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16. Abstract

Pressure signatures for a 0.0041-scale model of the space shuttle orbiter were measured in the wind tunnel at Mach numbers from 1.3 to 4.0. The angles of attack were 0°, 10°, 20°, and 30°. At each angle of attack the model was rolled from 0° to 120° in 30° increments.

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INTRODUCTION

The results of a previous sonic boom investigation which was conducted using a 0.0041-scale model of the latest space shuttle orbiter were presented in reference 1. The purpose of the previous investigation was to determine if differences existed in the sonic boom levels for two different space shuttle orbiters, namely the delta wing and the latest space shuttle configuration. Although the investigation was conducted over a sufficiently wide range of Mach numbers, the angle-of-attack range was limited to only two angles. As a result, sonic boom levels for certain attitudes of the latest orbiter could not be computed. For this reason, an investigation was conducted over wider ranges of Mach numbers and angles of attack than those given in reference 1. The results of the investigation are presented in this report.

SYMBOLS

h model altitude, distance between model reference and axis of static pressure probe (see fig. 3)

l reference length, body length

M Mach number

p reference pressure, free-stream static pressure

Δp incremental pressure due to flow field of model

Δx distance along abscissa of pressure signature

α angle of attack

ϕ roll angle

MODEL AND TEST PROCEDURES

A wind-tunnel sonic boom investigation, using a 0.0041-scale model of the latest space shuttle orbiter (fig. 1), was conducted in the 20-Inch Supersonic Wind Tunnel at the Jet Propulsion Laboratory. Although the components of the space shuttle orbiter are continuously being modified, the overall shape of the model is considered close enough to that of the full-scale orbiter for use in wind-tunnel sonic boom investigations. The model, which is constructed of steel, is complete except for the rocket engines.

Shown in figure 2 are installation photographs of the orbiter model at the various angles of attack.

A general layout of the model and the static pressure probe is shown in figure 3. The model is mounted on a linear actuator which travels longitudinally on a straight line parallel to the centerline of the wind tunnel. The static pressure probe shown in the figure below the model is a slender 2° (included angle) cone with four pressure orifices located at every 90° around the circumference of the cone. The orifices, which are manifolded into a common chamber, lie on a plane tangent to the ($M = 1.4$) Mach cone originating from the nose of the model. Experience has shown that this orifice configuration can be used to measure the pressure signatures at Mach numbers ranging from 1.3 to 4.0. The static pressure probe is mounted on spacers attached to the floor of the test section. With this arrangement, the height of the probe can be adjusted to prevent shock waves reflecting from the test section floor from interfering with the pressure signature.

The total pressure for Mach numbers 1.3 to 3.5 was 133.39 kN/m^2, and at Mach 4.0 the total pressure was 200.08 kN/m^2. The total pressures at Mach numbers 1.3 and 1.5 ($\alpha = 20°$) were 116.71 kN/m^2 and 104.04 kN/m^2, respectively. For these two cases the total pressures were reduced to prevent the maximum overpressures measured in the near field of the model from exceeding the capacity of the pressure transducer.

The table below shows the test Mach numbers and angles of attack.

	Mach number						
	1.3	1.5	2.0	2.5	3.0	3.5	4.0
α, deg	0	0	0	0			
	10	10	10	10	10	10	10
	20	20	20	20	20	20	20
				30	30	30	30

At each angle of attack, the model and sting were rolled from 0° to 120° in 30° increments.

PRESENTATION OF THE DATA

Data are presented in the form of schlieren photographs and pressure signatures. Schlieren photographs are presented in figures 4 through 25, and pressure signatures are presented in figures 26 through 47.

REFERENCE

1. Mendoza, Joel P.: Wind Tunnel Pressure Signatures for a 0.0041-Scale Model of the Space Shuttle Orbiter. NASA TM X-62,432, 1975.

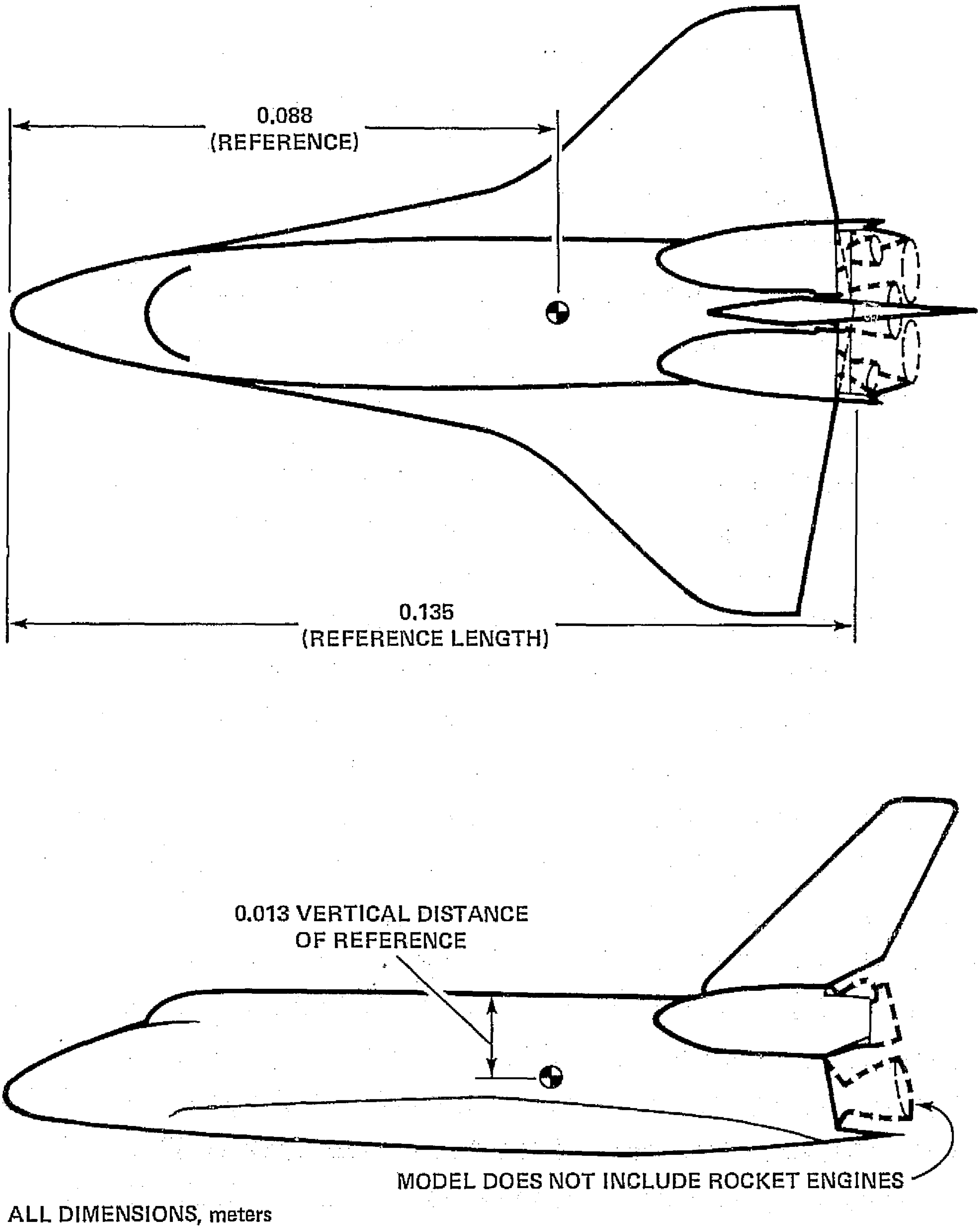

Figure 1.- The 0.0041-scale model of the latest space shuttle orbiter.

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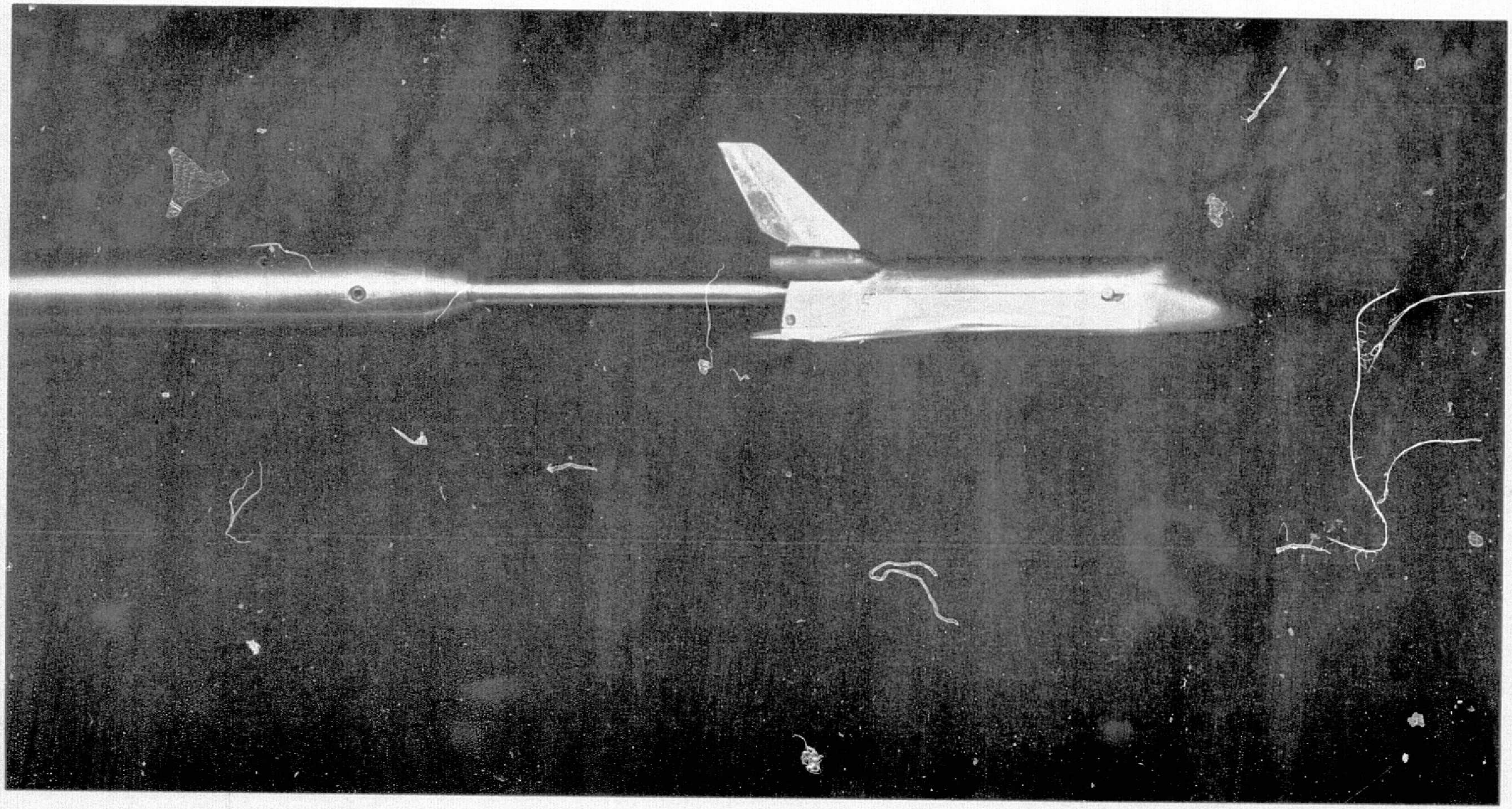
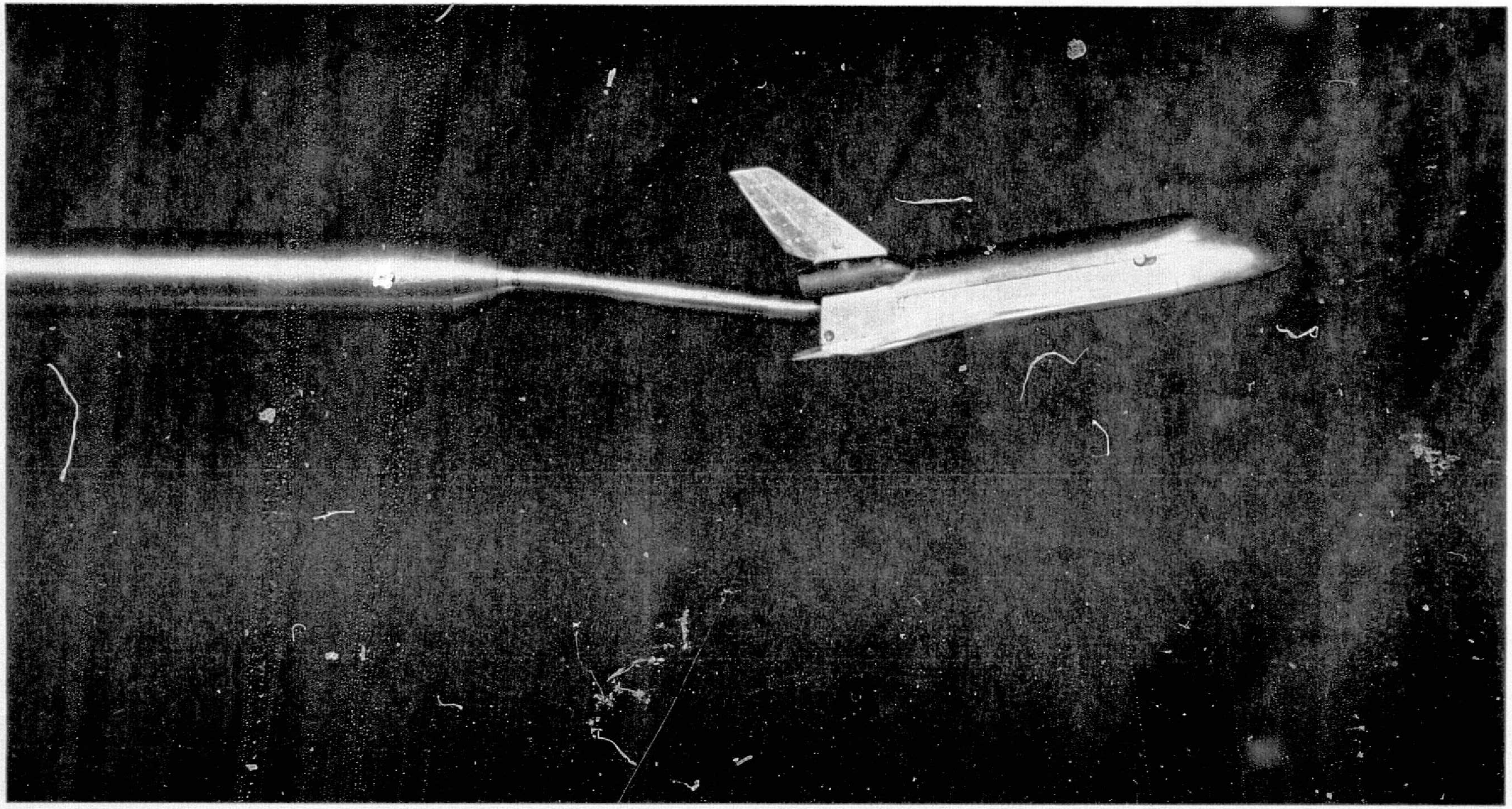


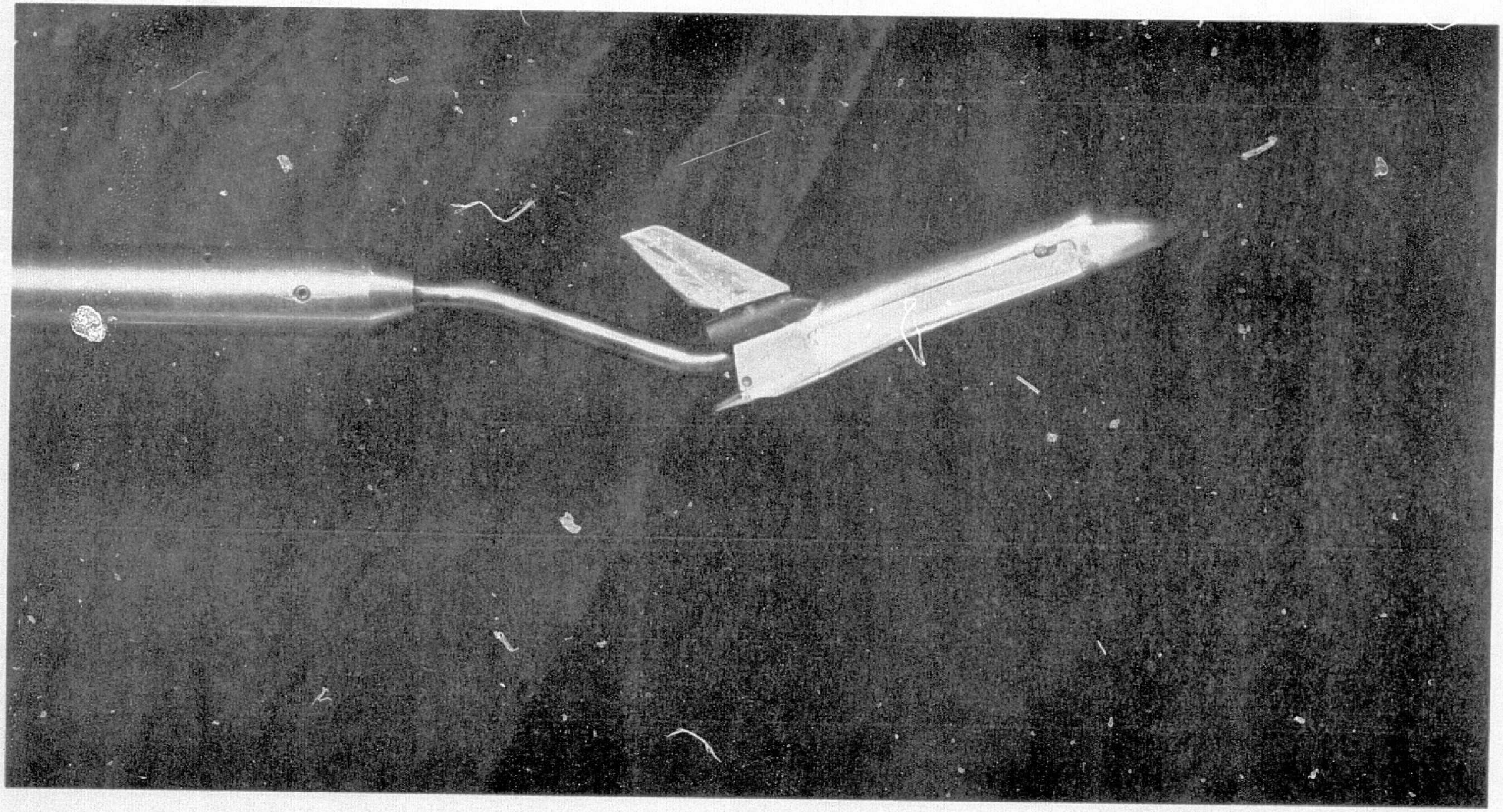
(a) $\alpha = 0°$

Figure 2.- Installation photographs of the 0.00041-scale model of the space shuttle orbiter.



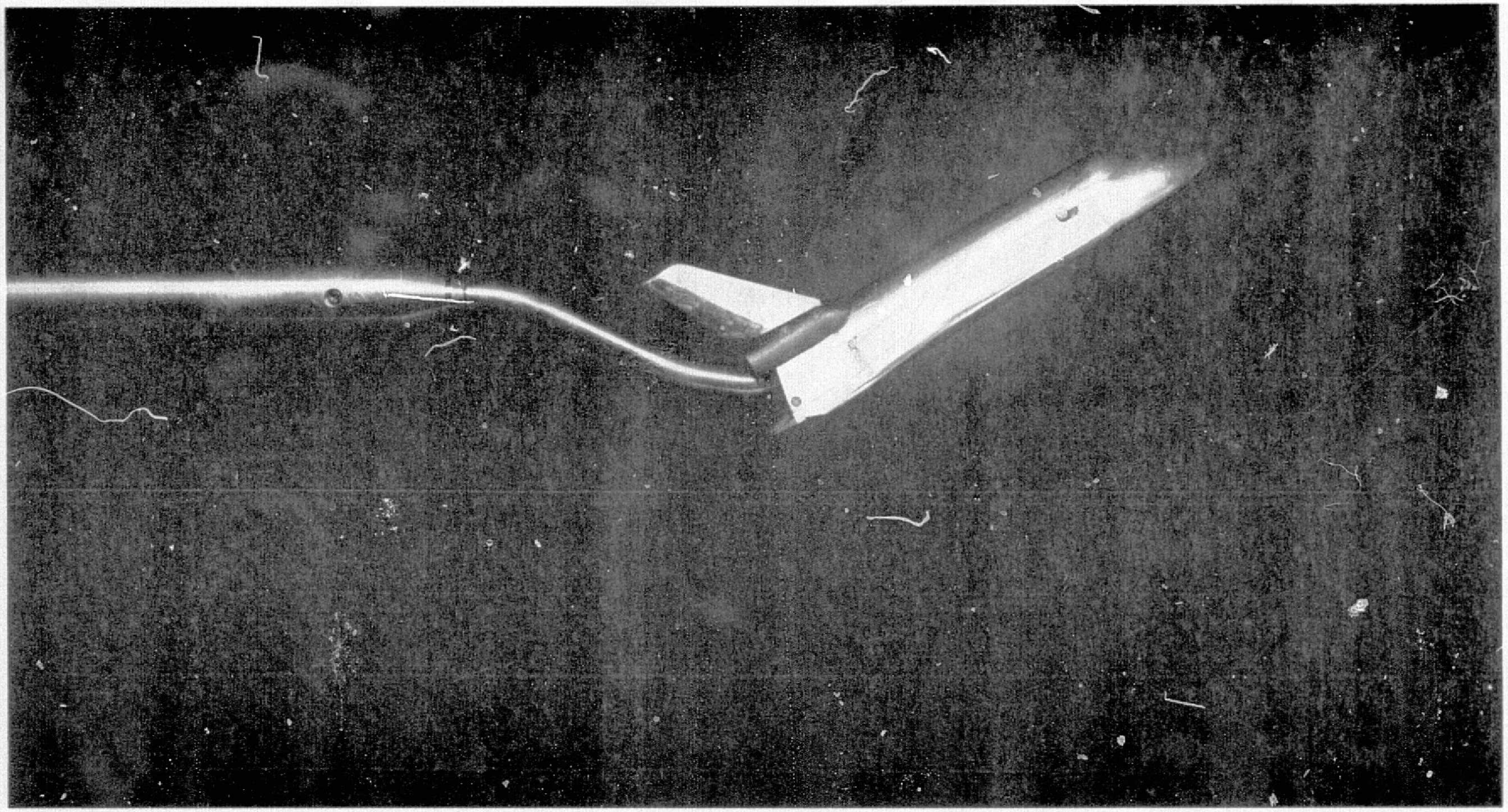
(b) $\alpha = 10°$

Figure 2.- Continued.



(c) $\alpha = 20°$

Figure 2.- Continued.



(d) α = 30°

Figure 2.- Concluded.

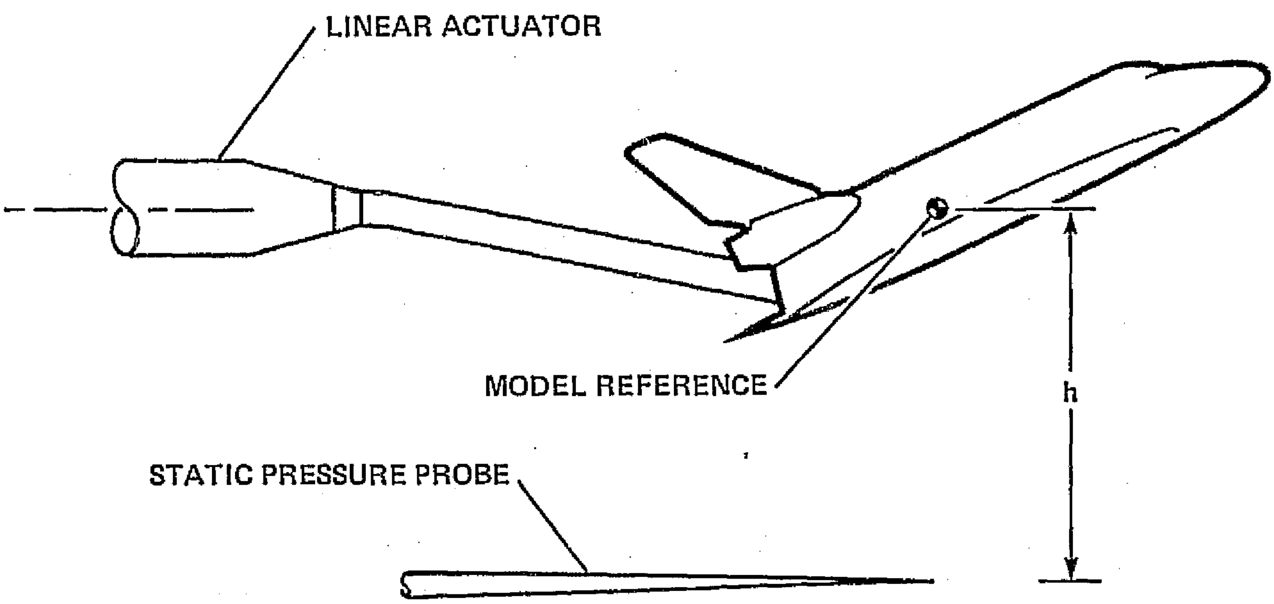
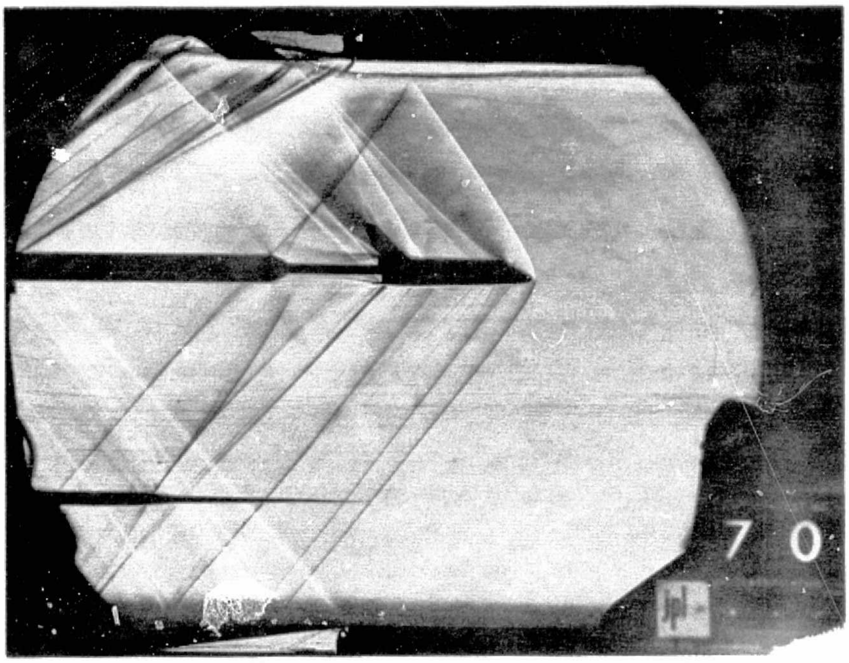
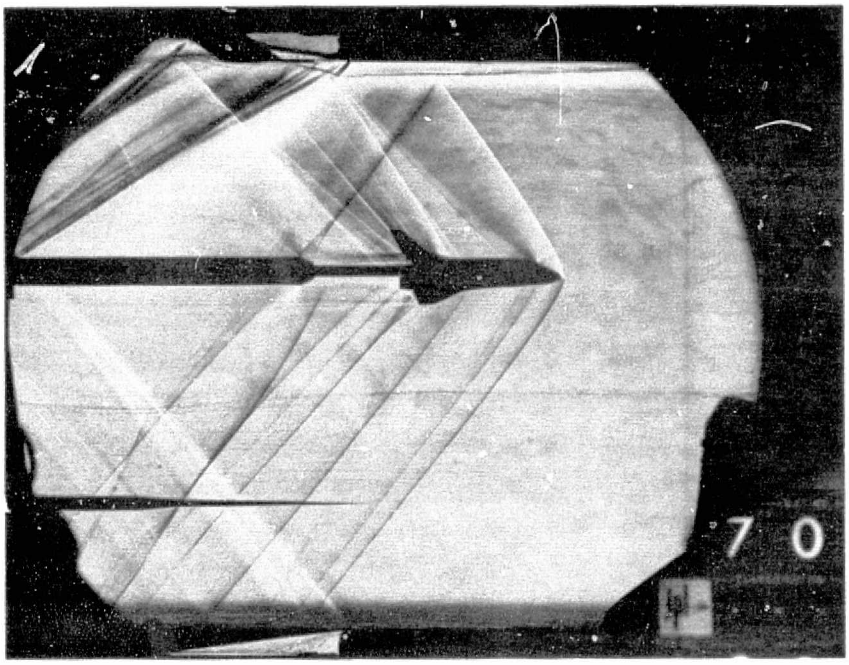


Figure 3.- General arrangement of the 0.0041-scale model and static pressure probe.

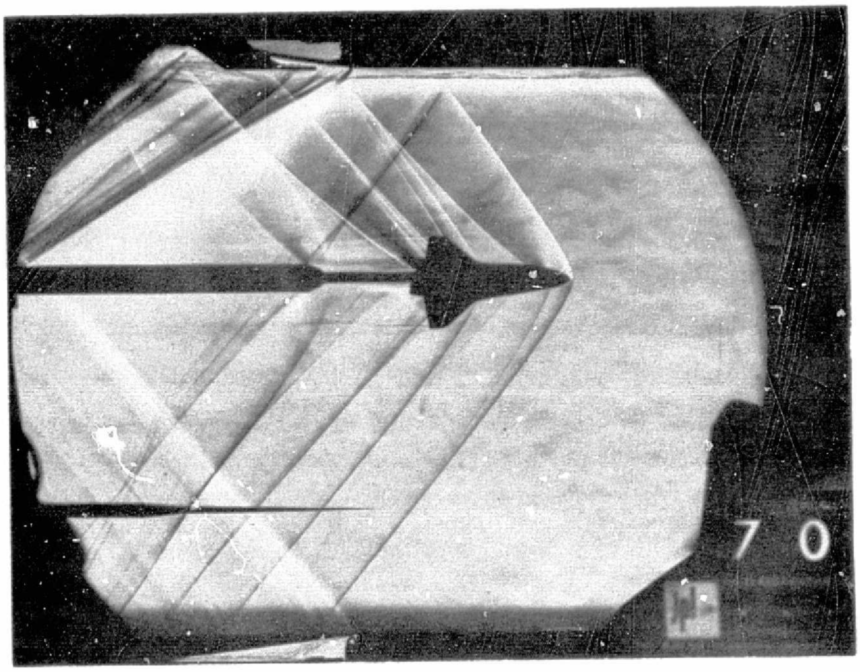


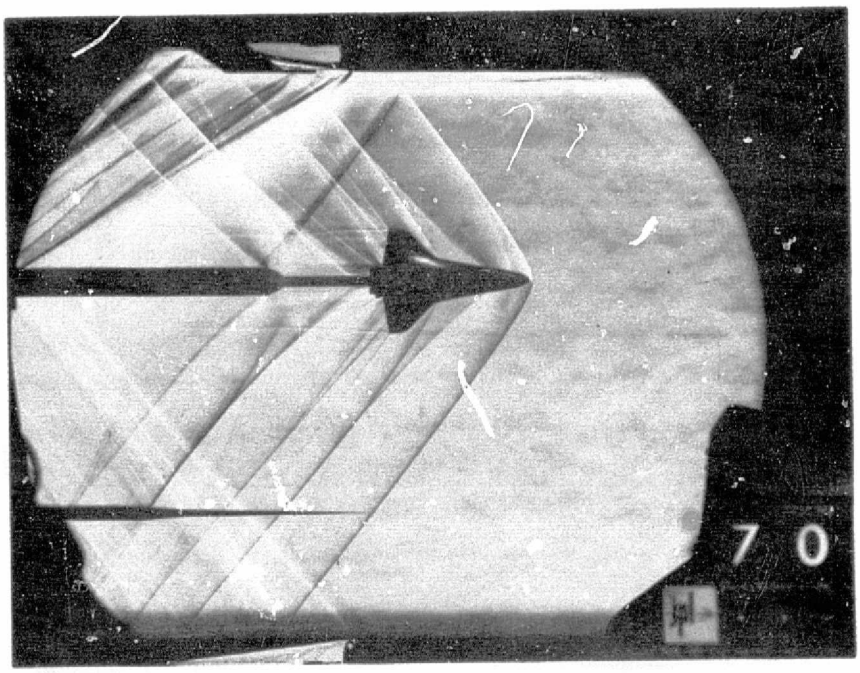


(a) ϕ = 0°

(b) ϕ = 30°

Figure 4.- Schlieren photographs, M = 1.3, α = 0°, h/l = 1.55.

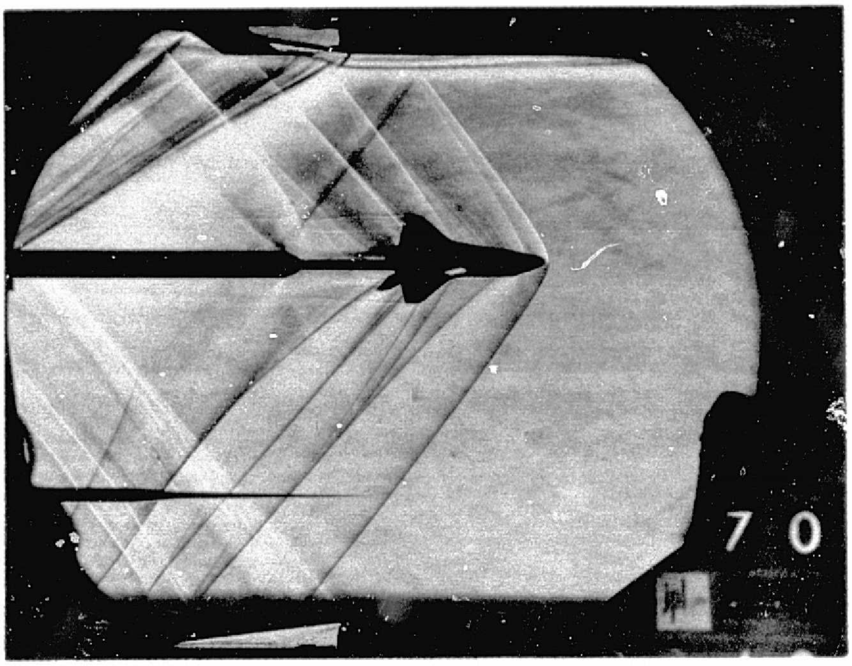




(c) $\phi = 60°$

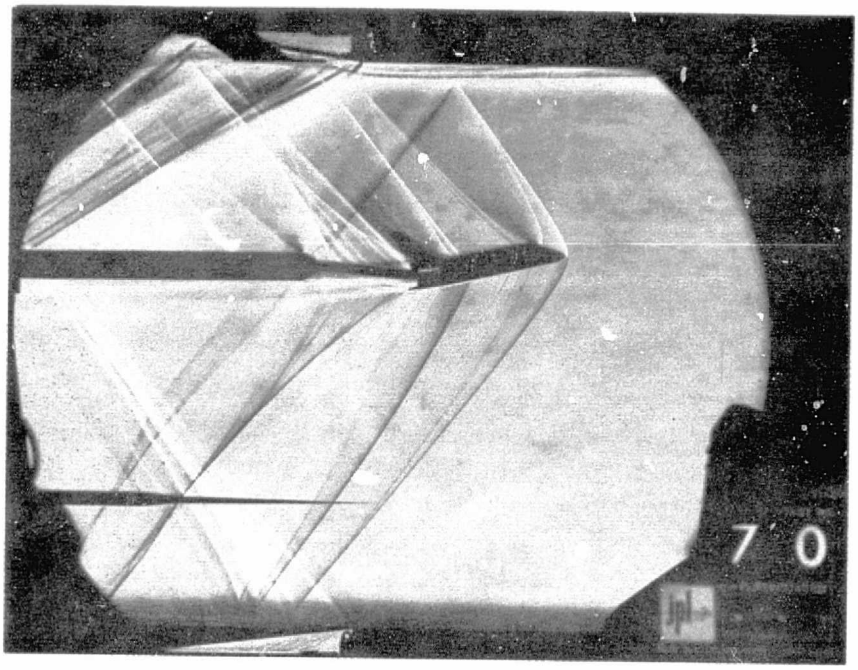
(d) $\phi = 90°$

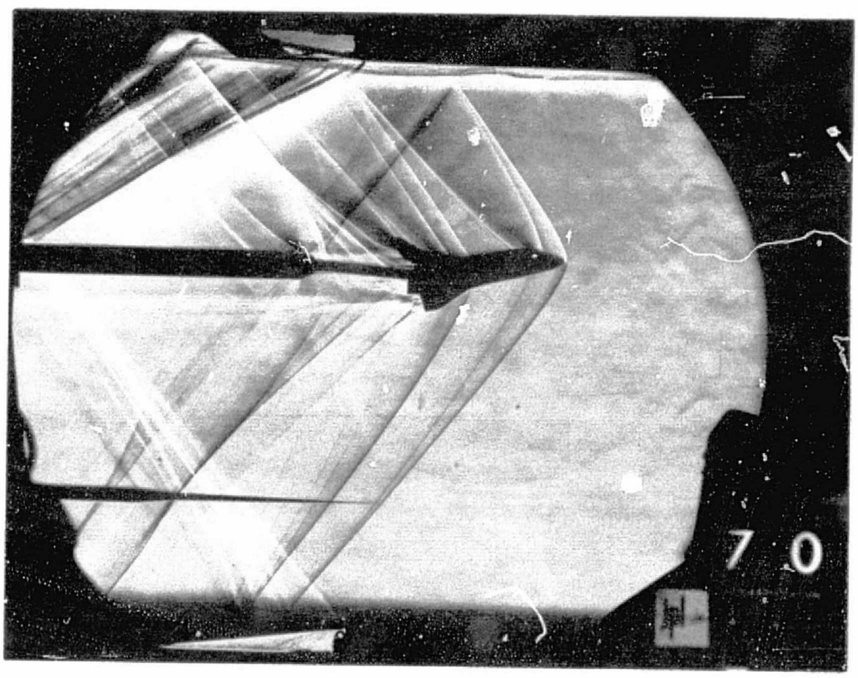
Figure 4.- Continued.



(e) $\phi = 120°$

Figure 4.- Concluded.

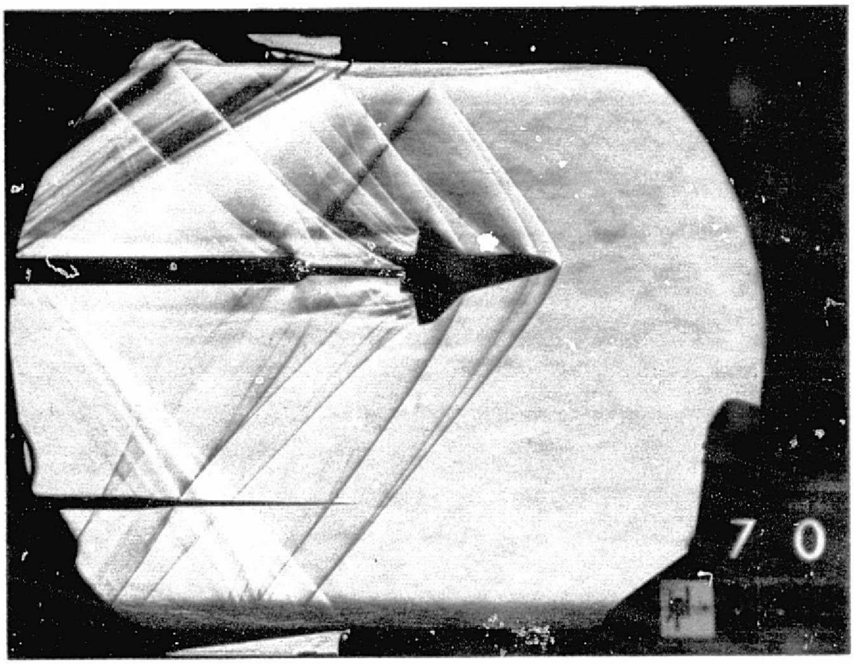


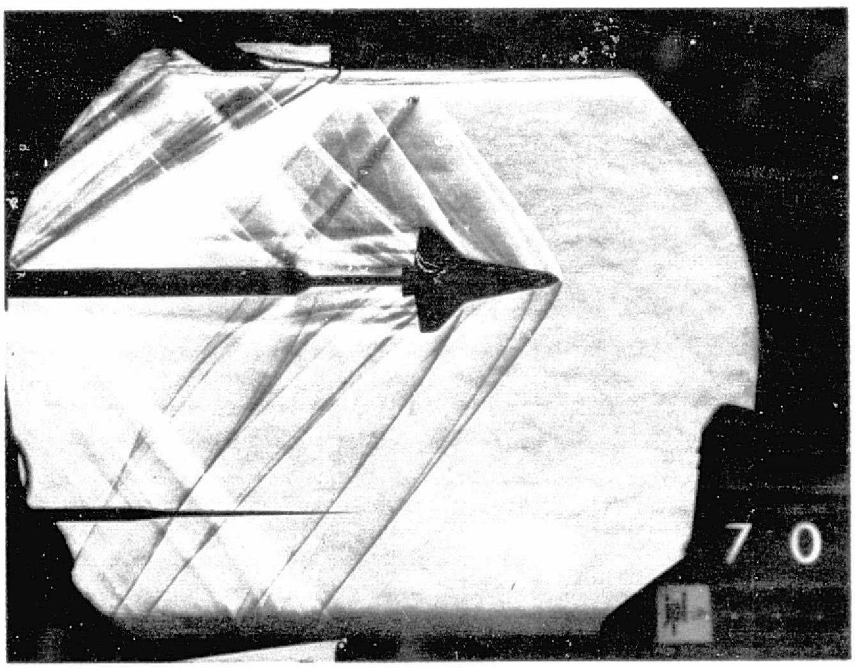


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 5.- Schlieren photographs, $M = 1.3$, $\alpha = 10°$, $h/l = 1.55$.

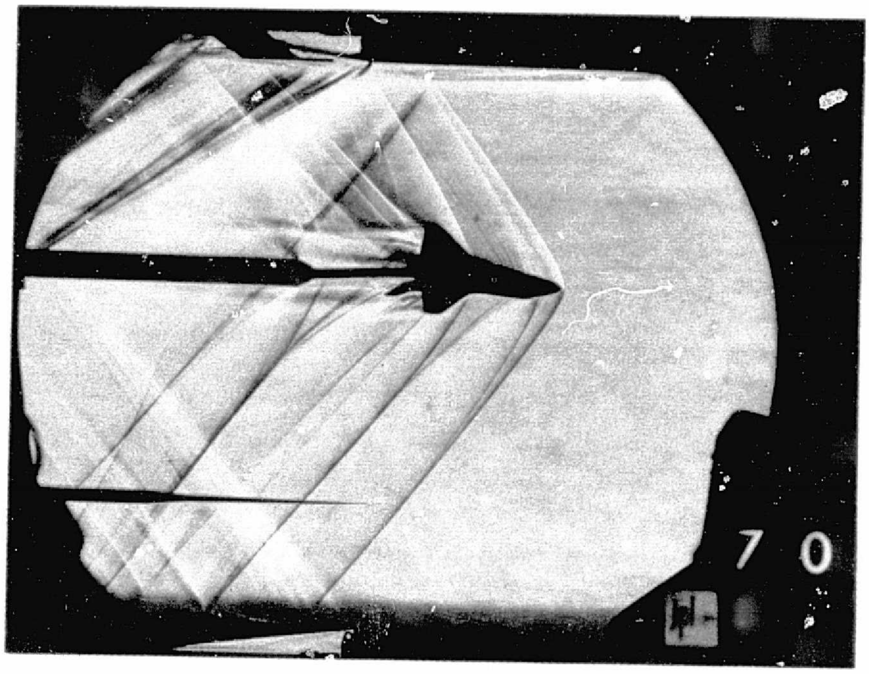




(c) $\phi = 60°$

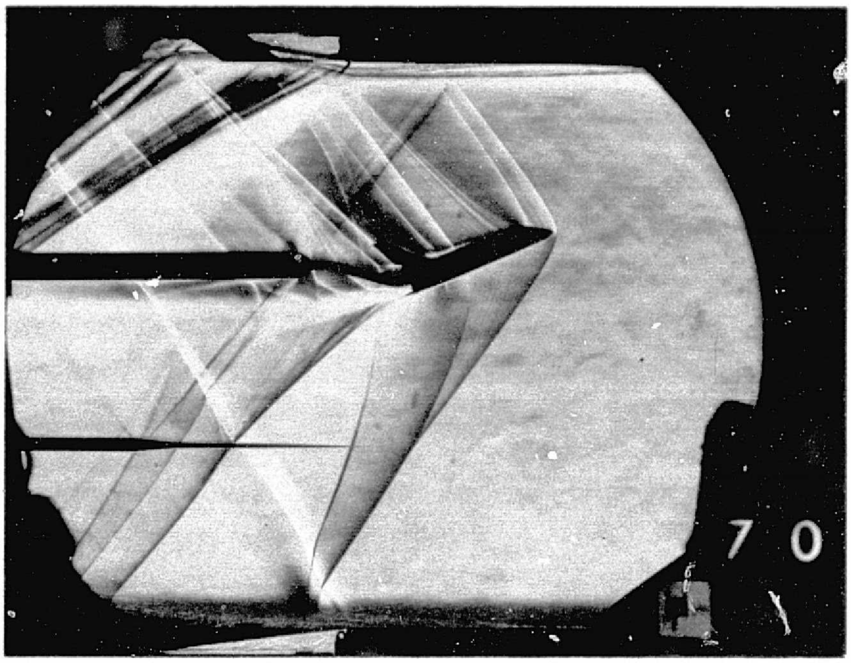
(d) $\phi = 90°$

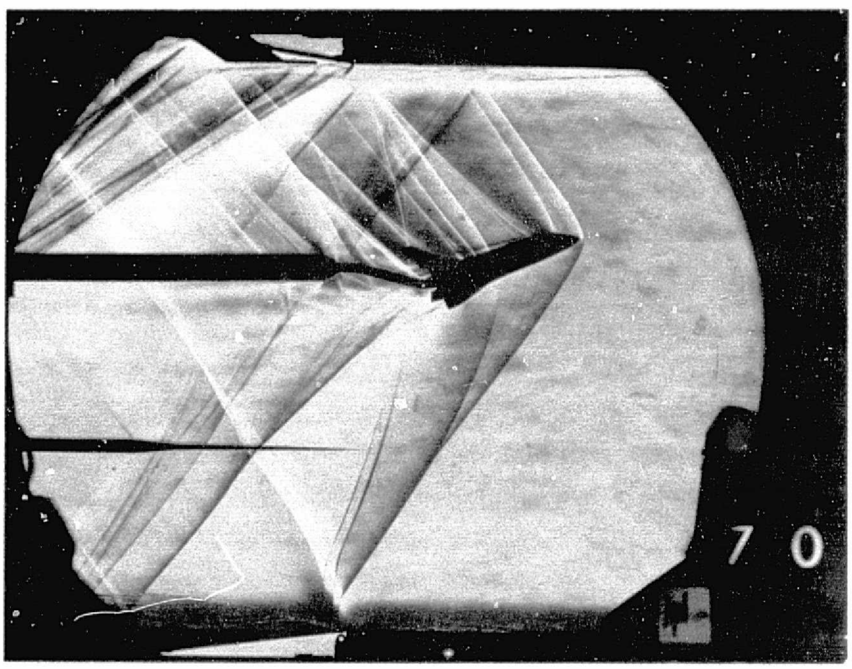
Figure 5.- Continued.



(e) $\phi = 120°$

Figure 5.- Concluded.

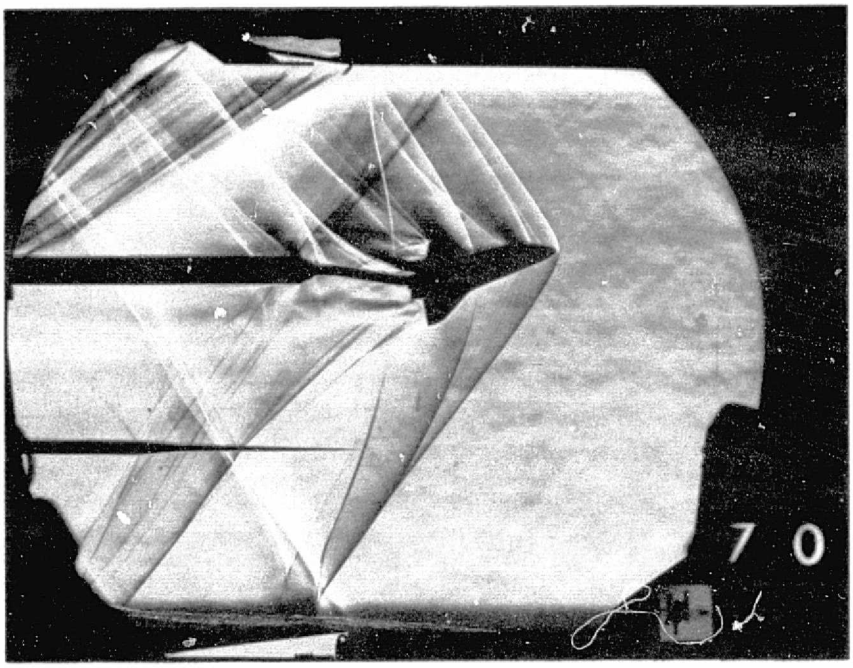


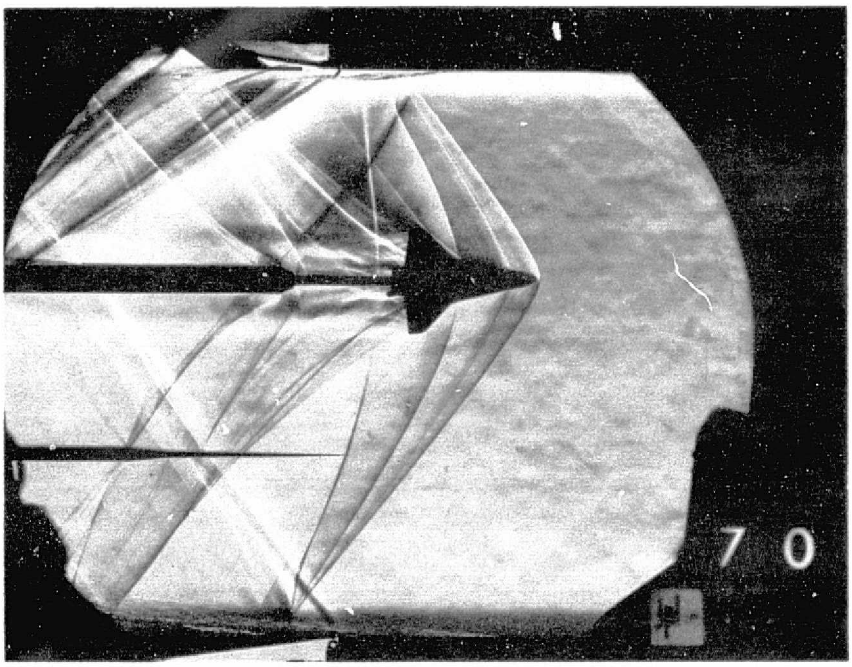


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 6.- Schlieren photographs, $M = 1.3$, $\alpha = 20°$, $h/l = 1.18$.

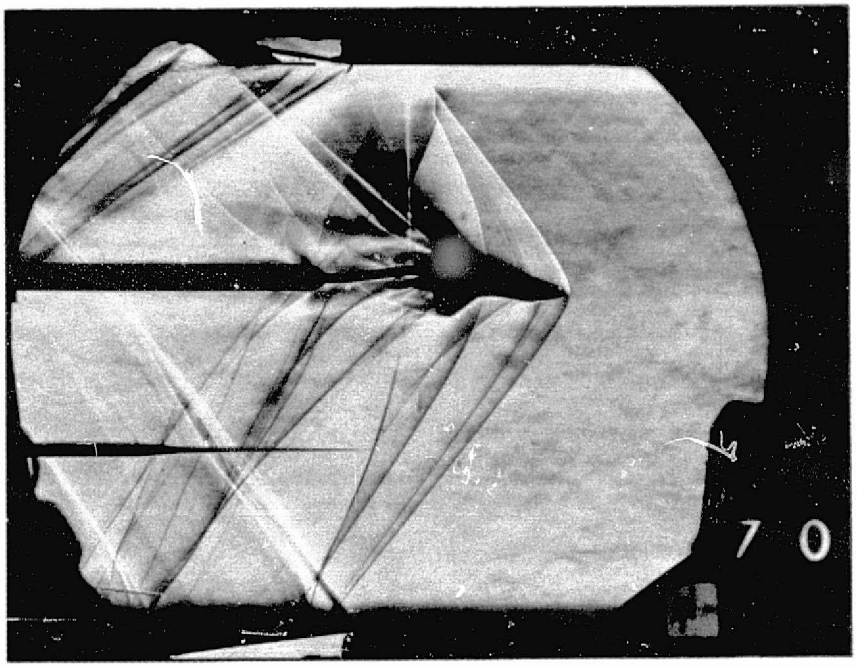




(c) ϕ = 60°

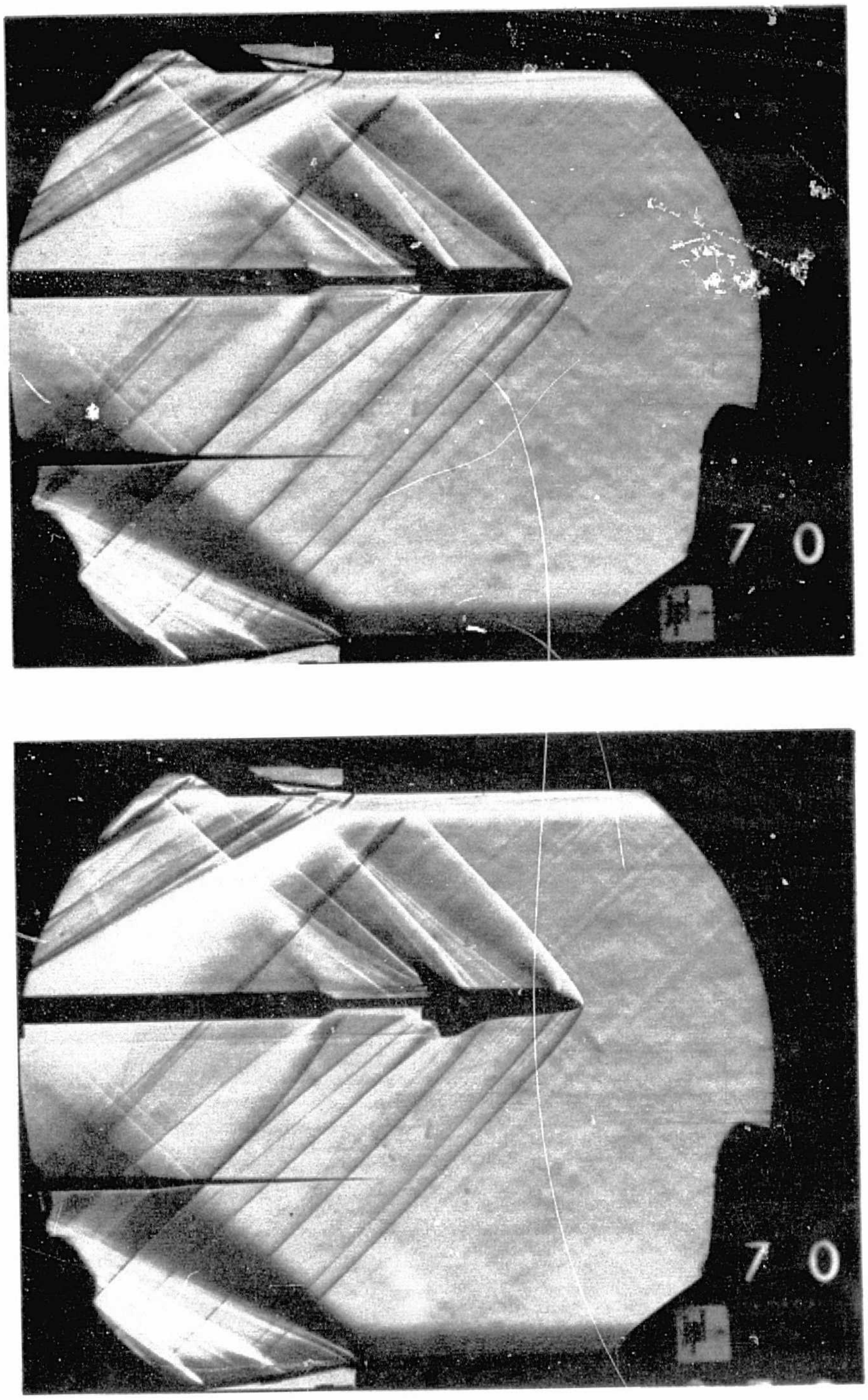
(d) ϕ = 90°

Figure 6.- Continued.



(e) ϕ = 120°

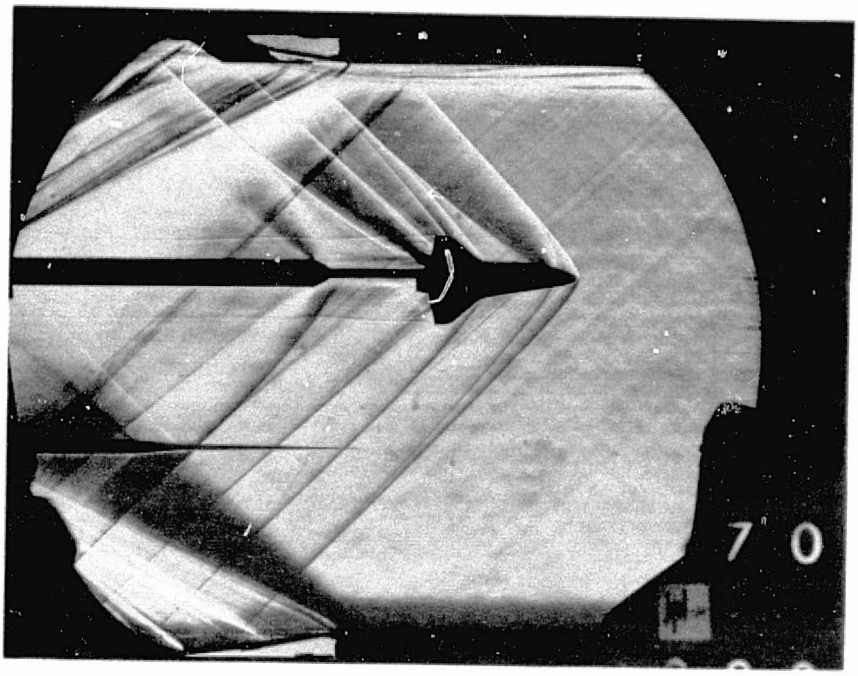
Figure 6.- Concluded.

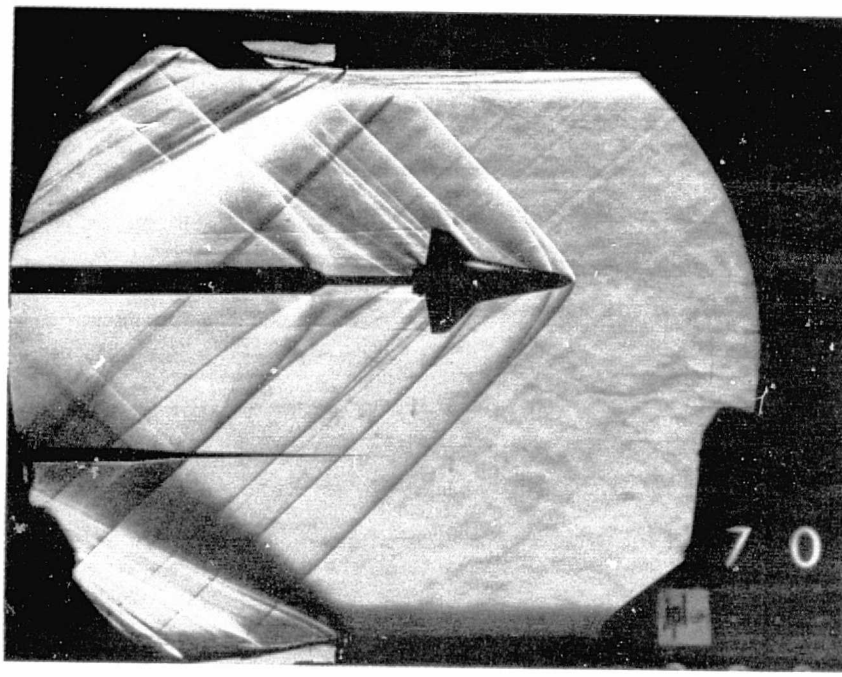


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 7.- Schlieren photographs, $M = 1.5$, $\alpha = 0°$, $h/l = 1.18$.

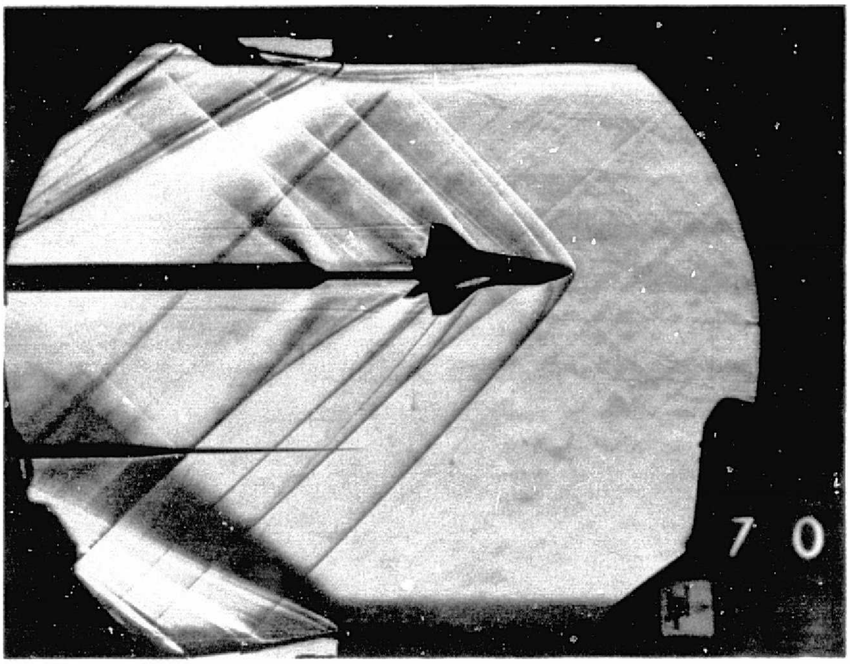




(c) ϕ = 60°

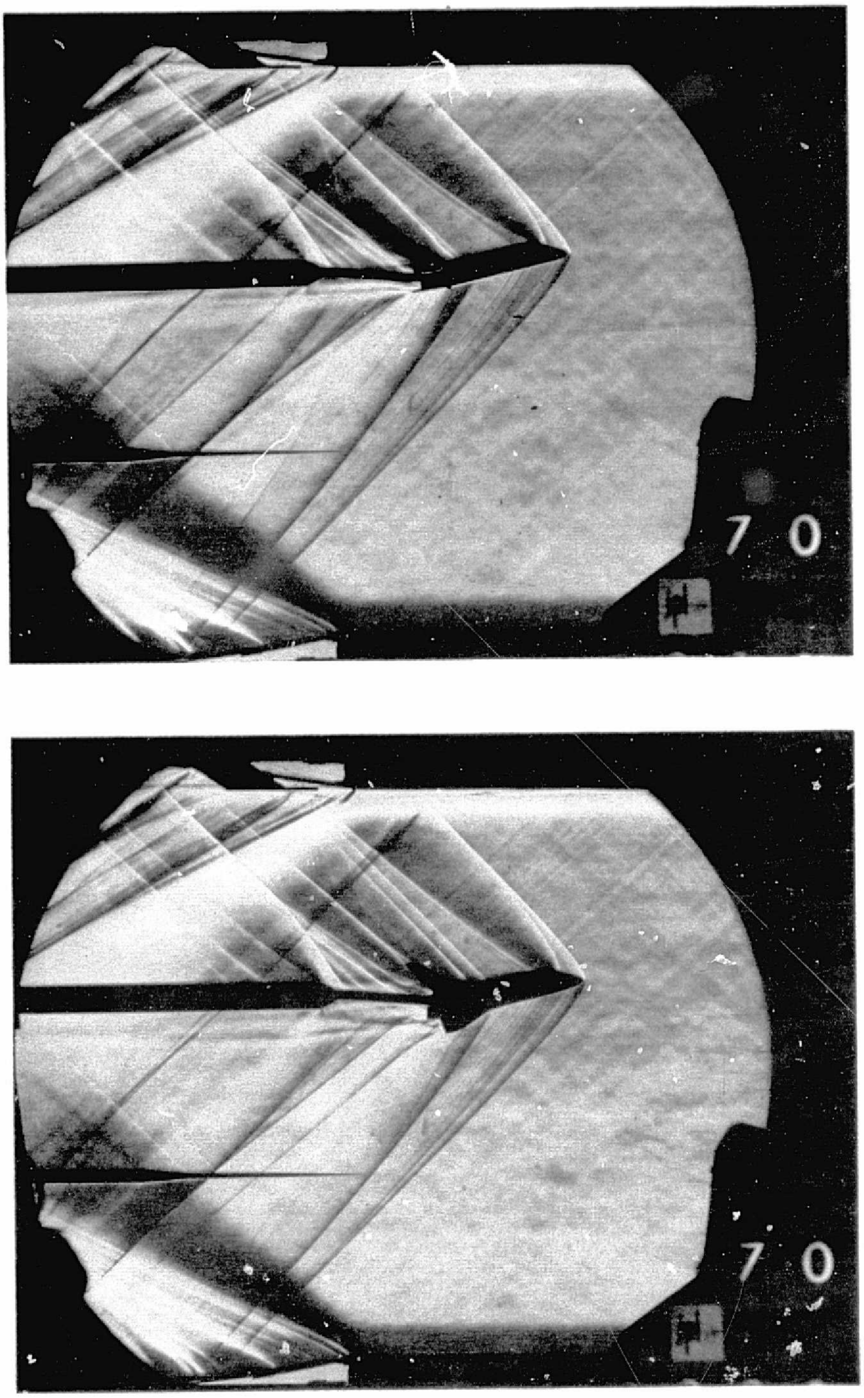
(d) ϕ = 90°

Figure 7.- Continued.



(e) $\phi = 120°$

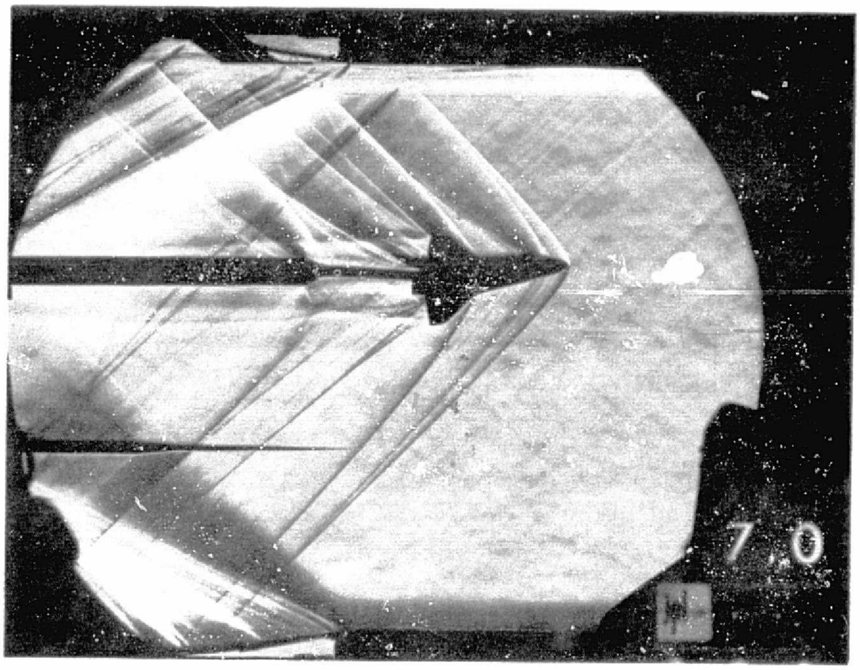
Figure 7.- Concluded.

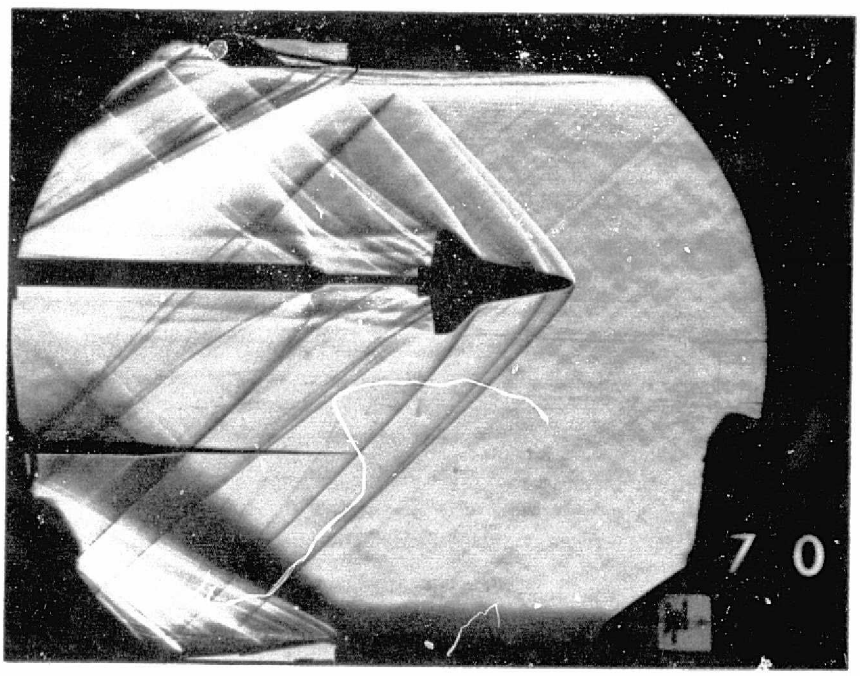


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 8.- Schlieren photographs, $M = 1.5$, $\alpha = 10°$, $h/l = 1.18$.

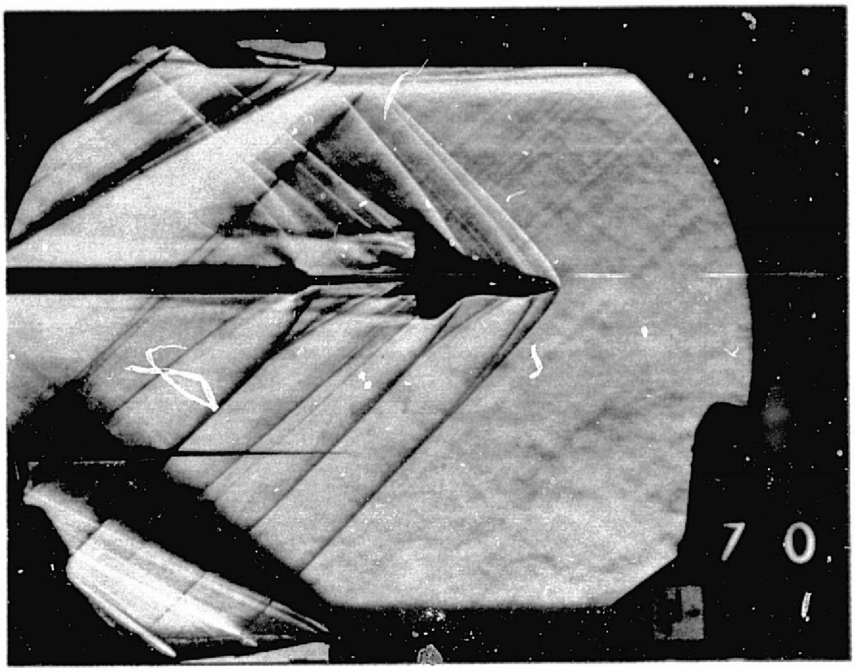




(c) $\phi = 60°$

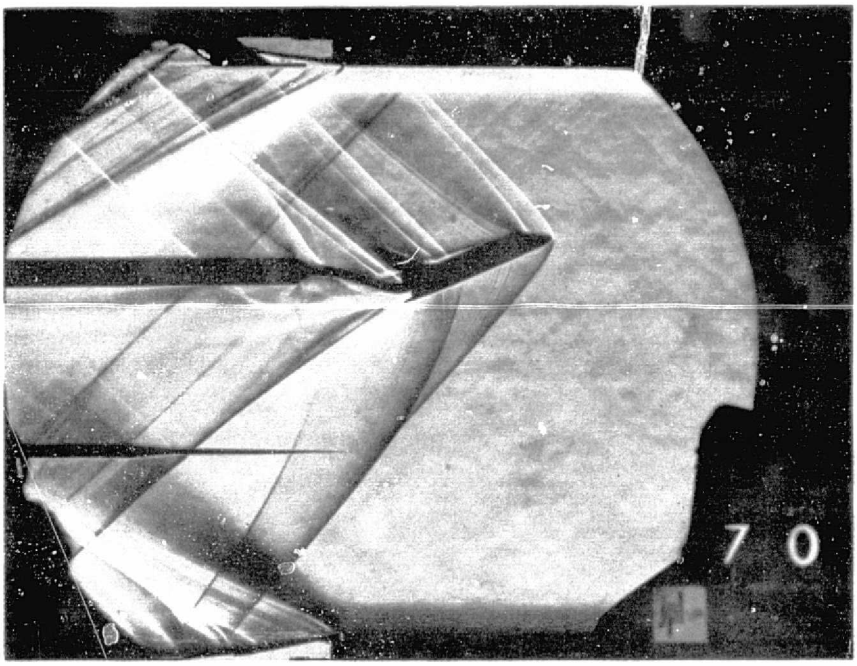
(d) $\phi = 90°$

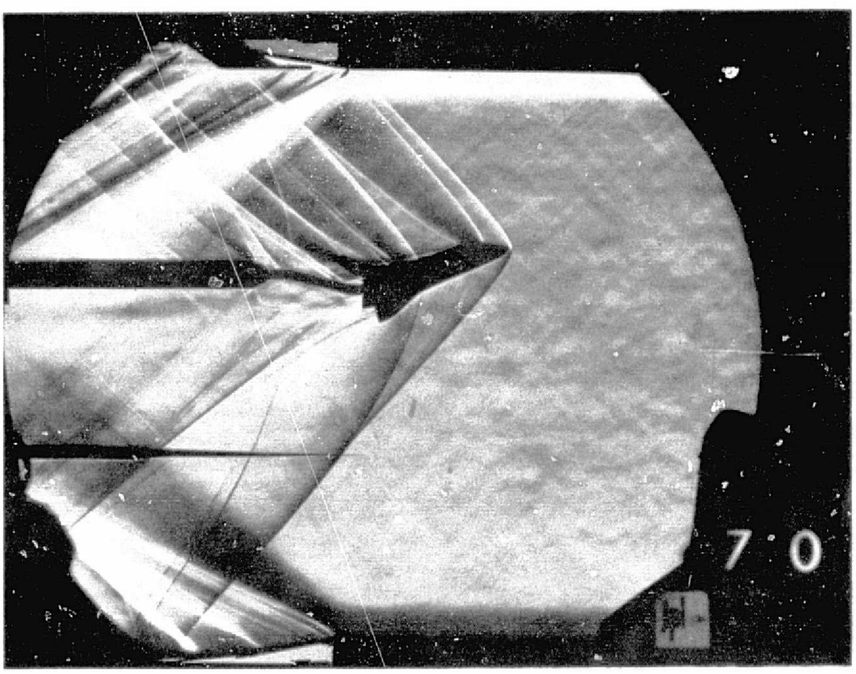
Figure 8.- Continued.



(e) ϕ = 120°

Figure 8.- Concluded.

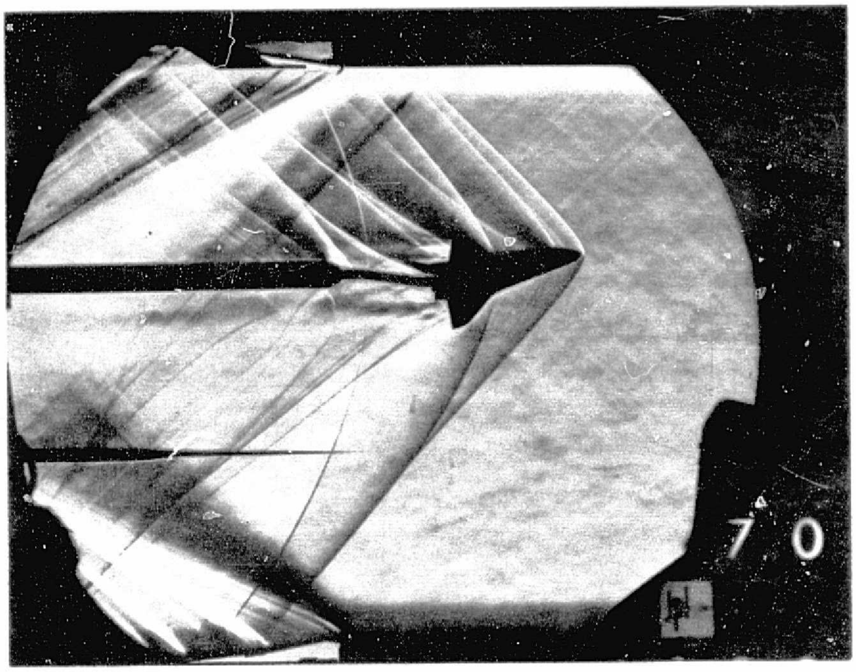


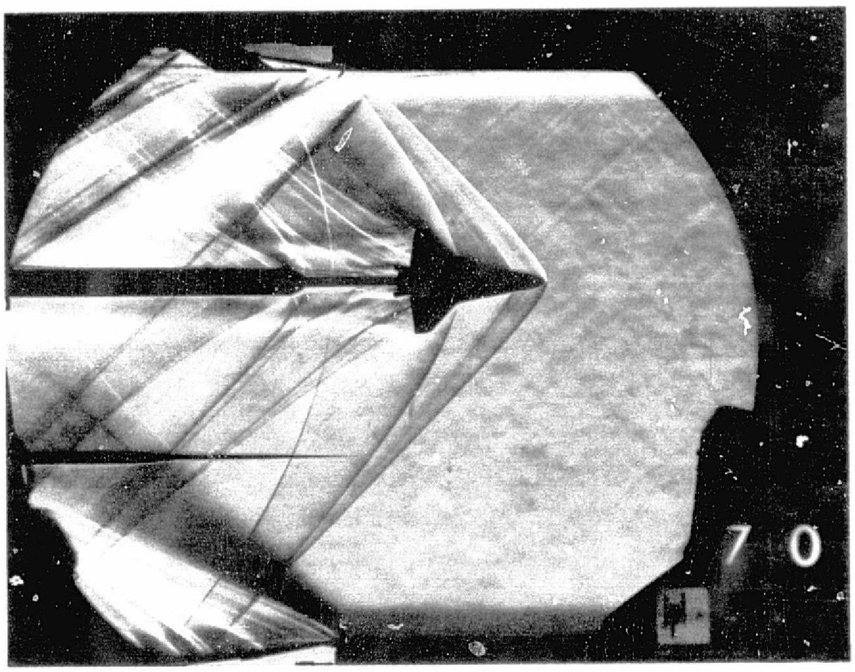


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 9.- Schlieren photographs, $M = 1.5$, $\alpha = 20°$, $h/l = 1.18$.

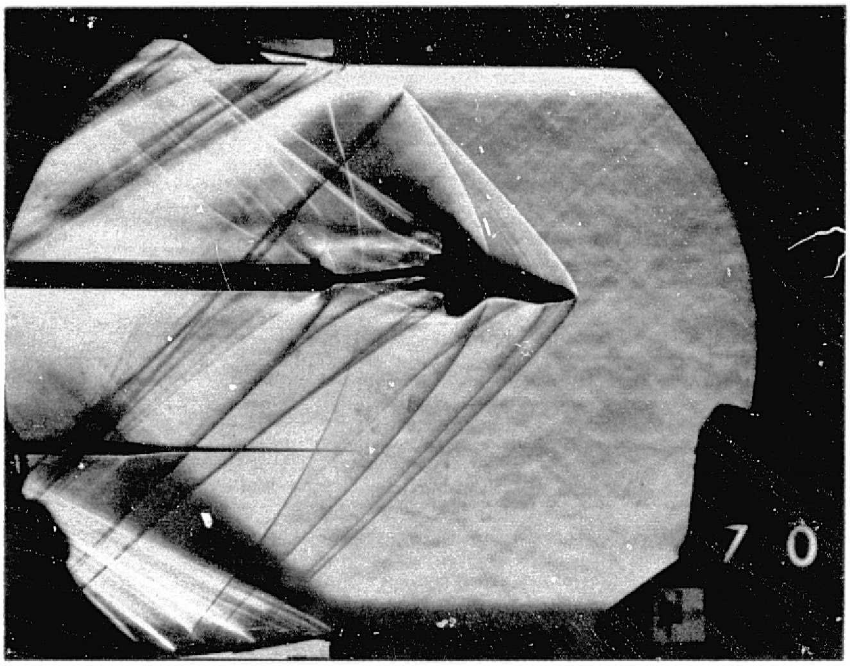




(c) $\phi = 60°$

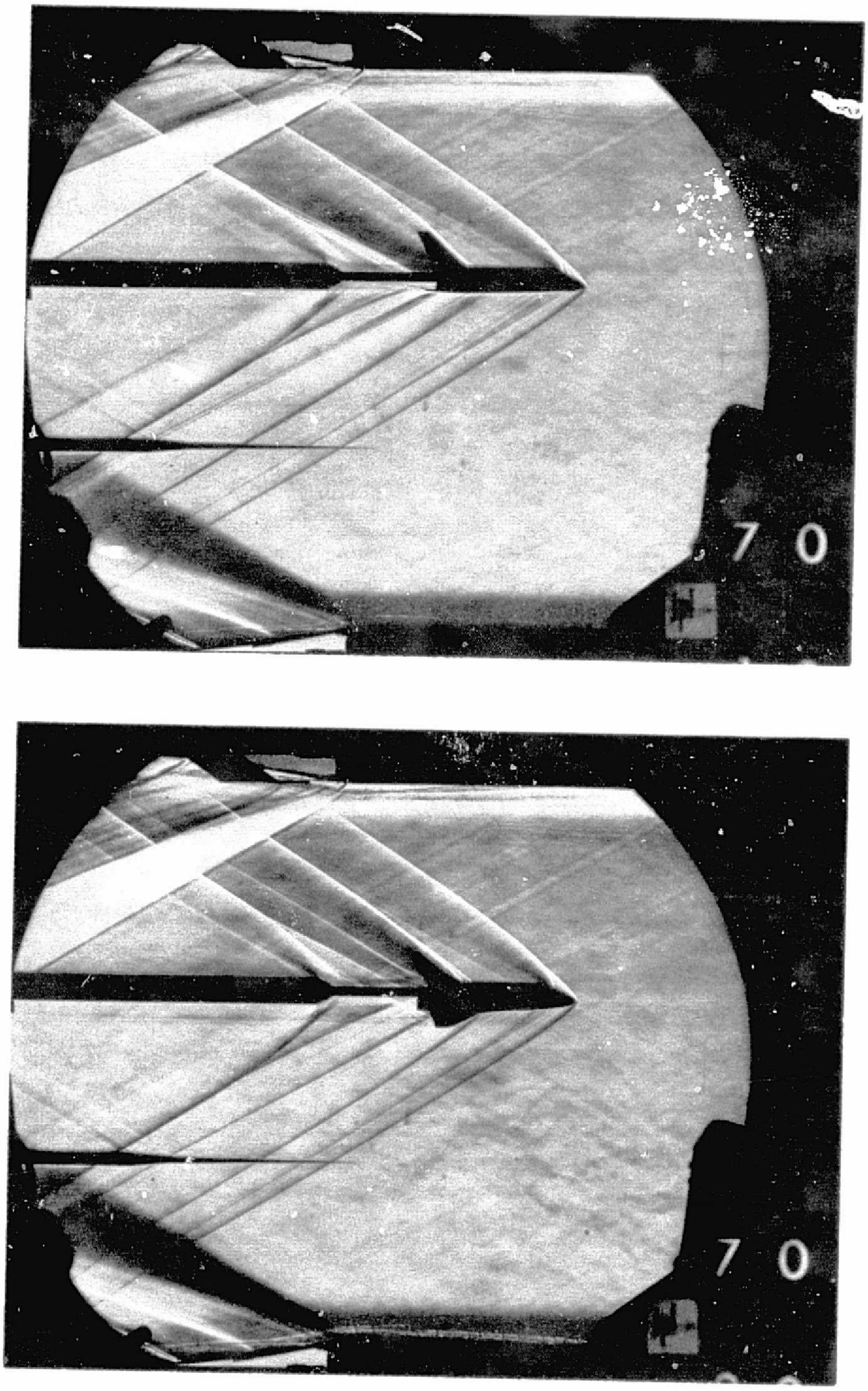
(d) $\phi = 90°$

Figure 9.- Continued.



(e) ϕ = 120°

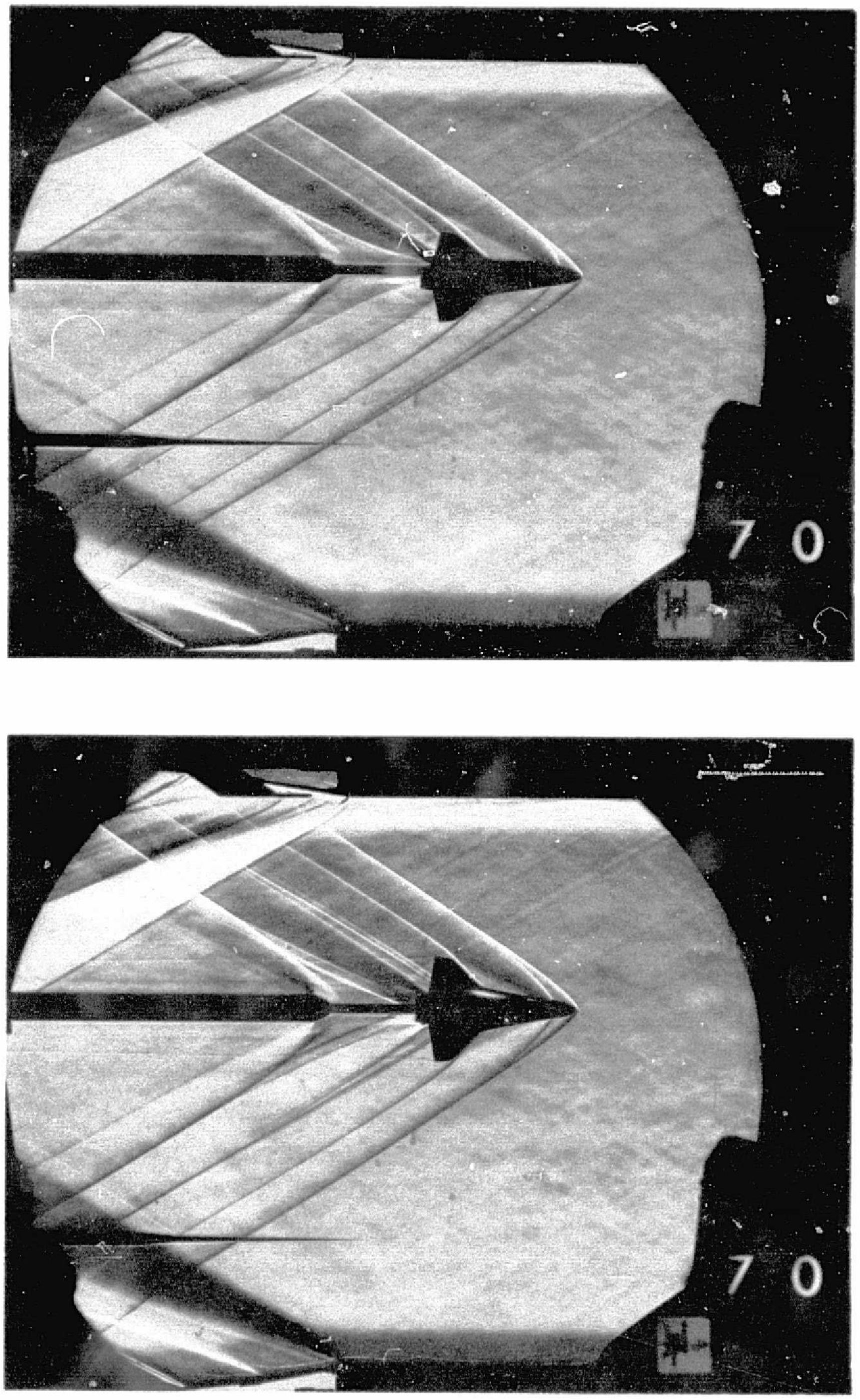
Figure 9.- Concluded.



(a) $\phi = 0°$, $h/l = 1.18$

(b) $\phi = 30°$, $h/l = 1.18$

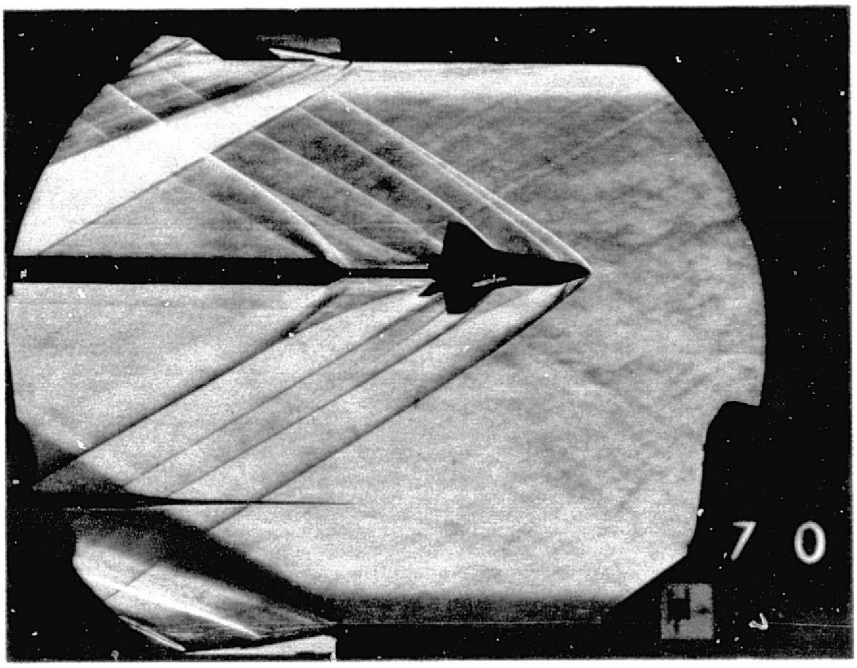
Figure 10.- Schlieren photographs, $M = 2.0$, $\alpha = 0°$.



(c) ϕ = 60°, h/l = 1.18

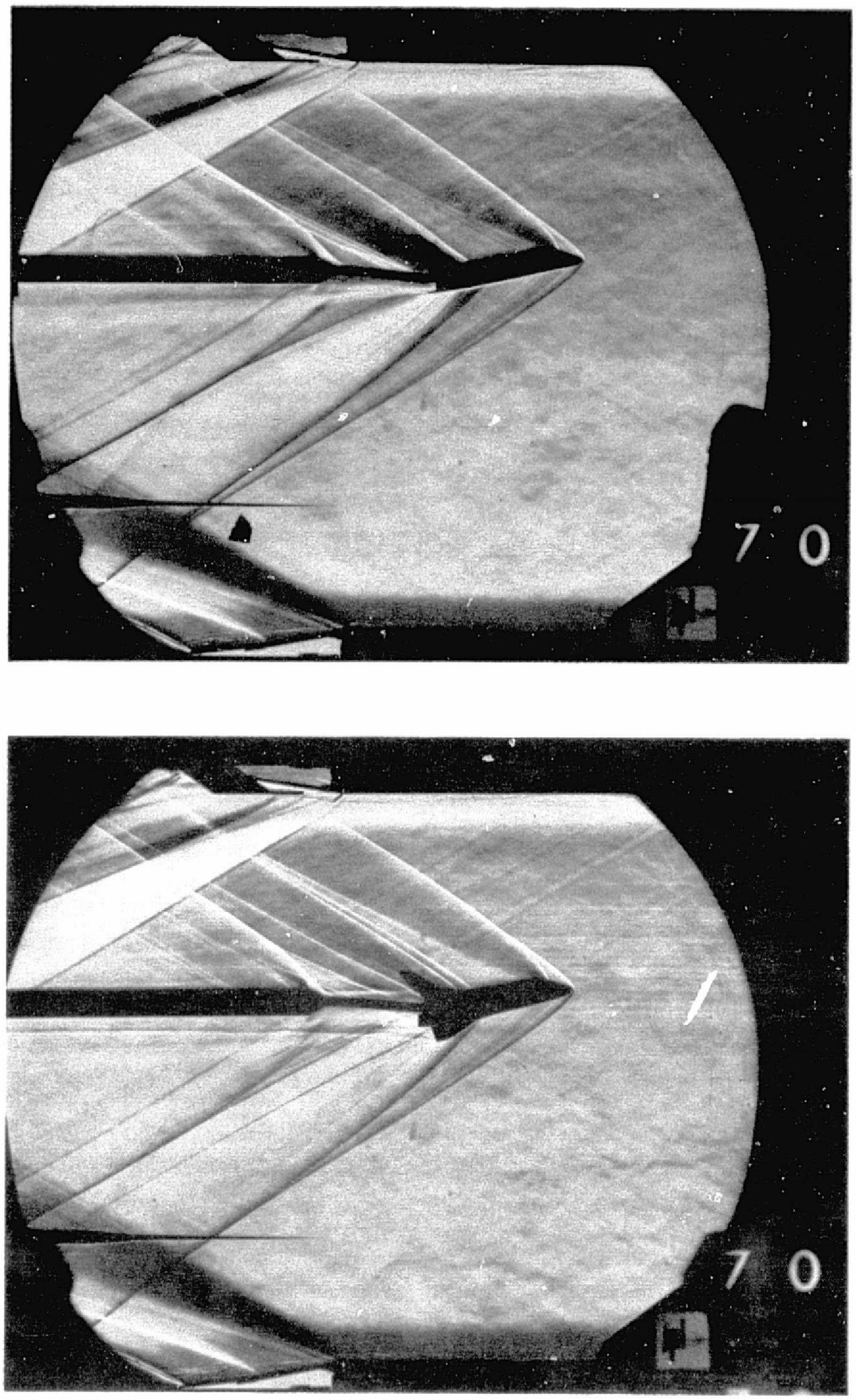
(d) ϕ = 90°, h/l = 1.55

Figure 10.- Continued.



(e) $\phi = 120°$, $h/l = 1.55$

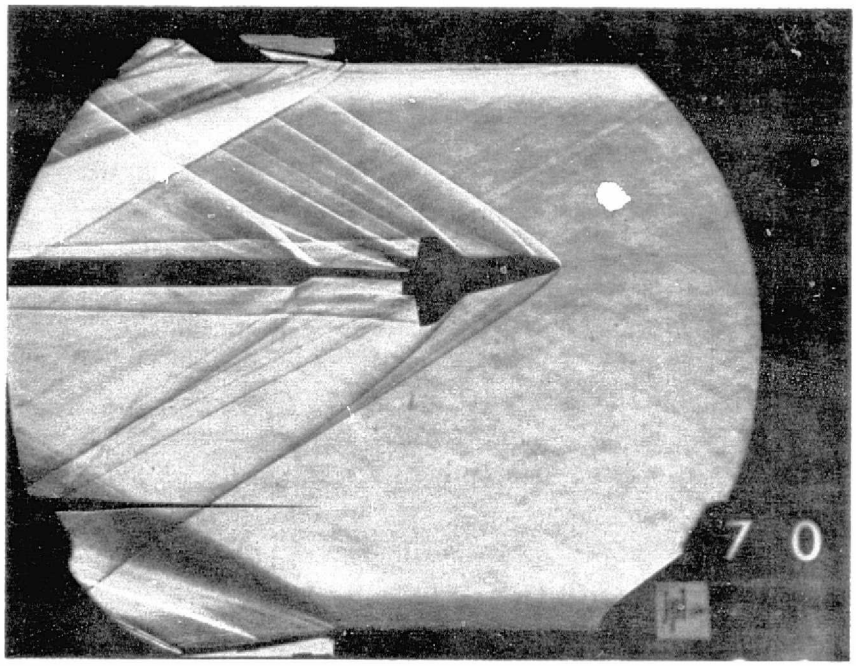
Figure 10.- Concluded.

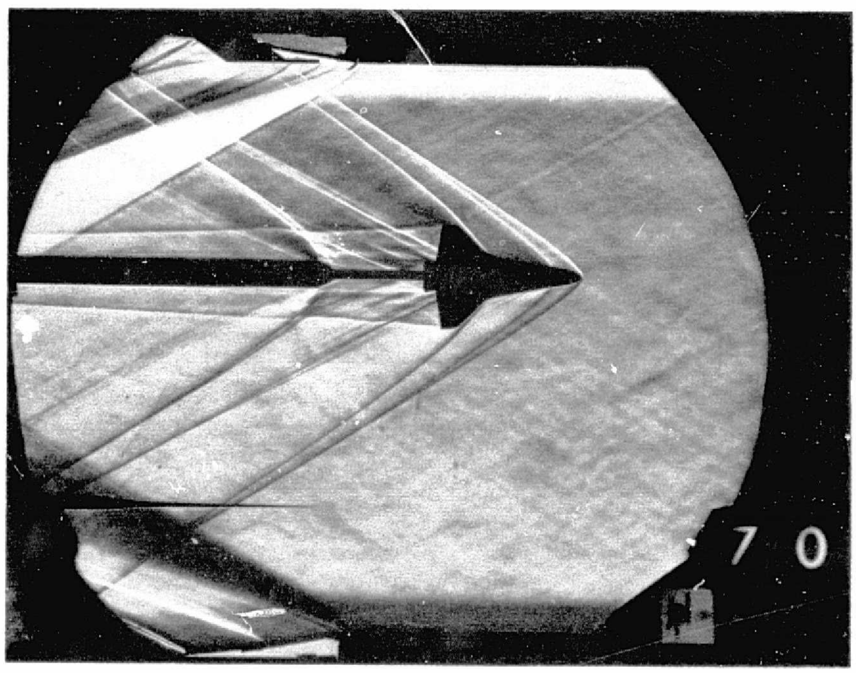


(a) ϕ = 0°

(b) ϕ = 30°

Figure 11.- Schlieren photographs, M = 2.0, α = 10°, h/l = 1.55.

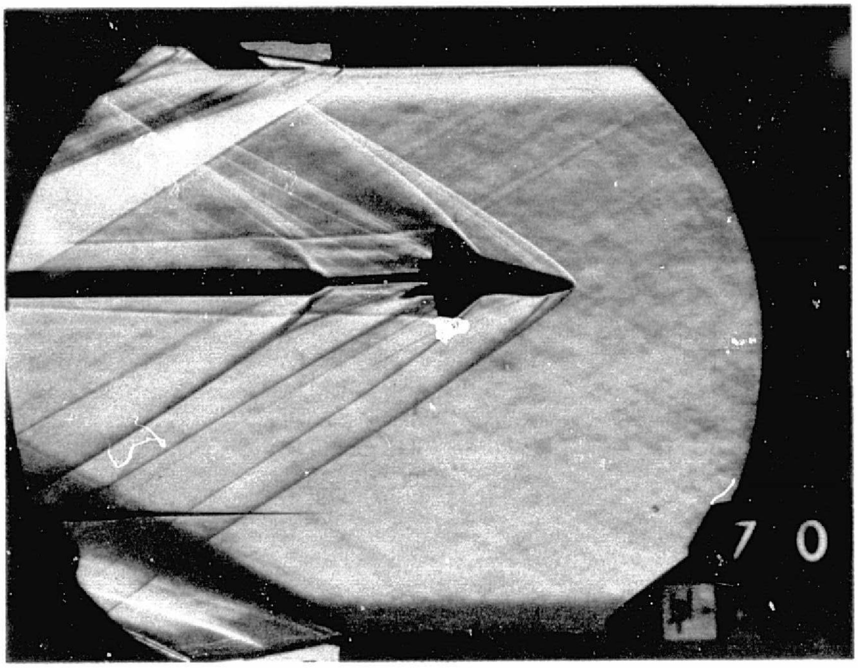




(c) ϕ = 60°

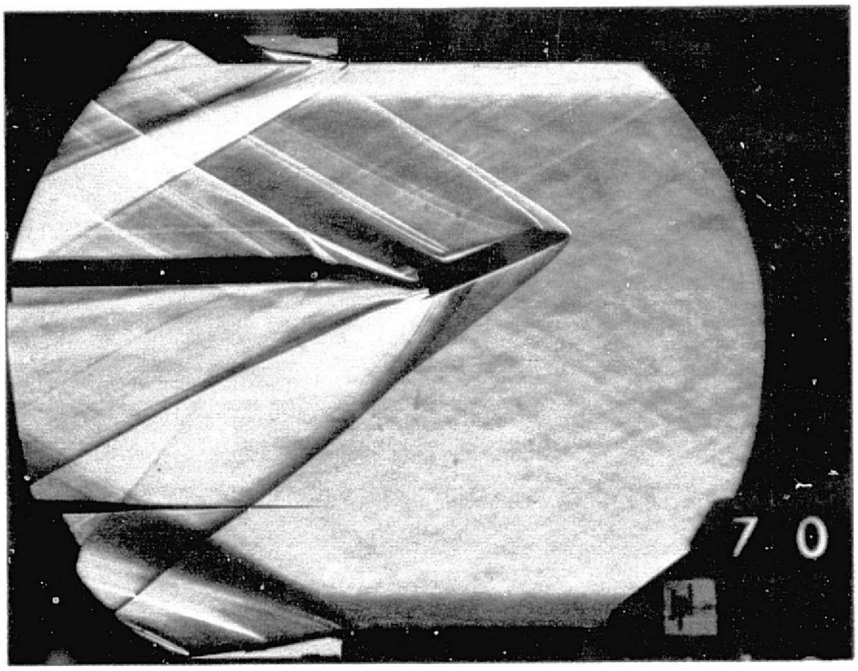
(d) ϕ = 90°

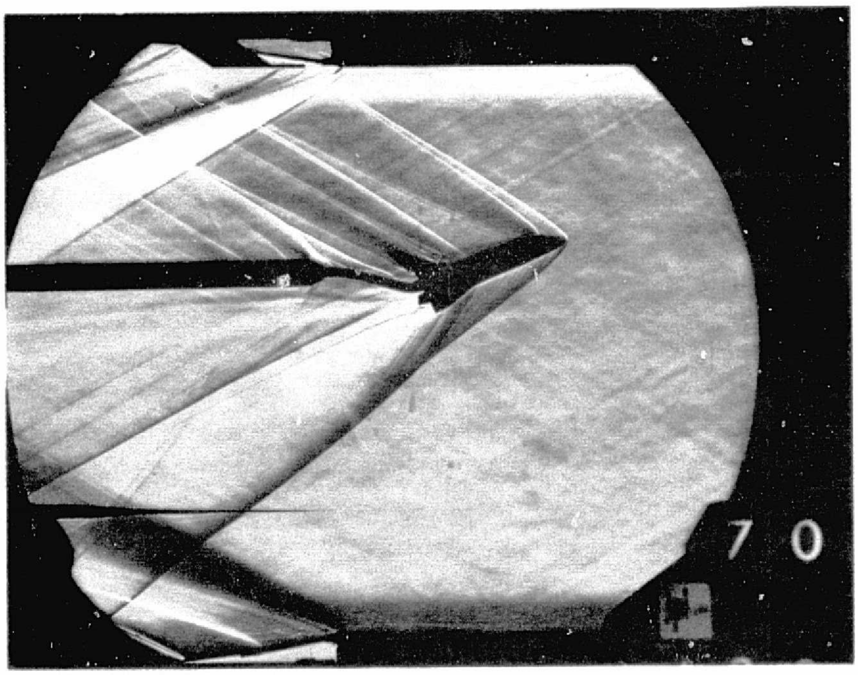
Figure 11.- Continued.



(e) $\phi = 120°$

Figure 11.- Concluded.

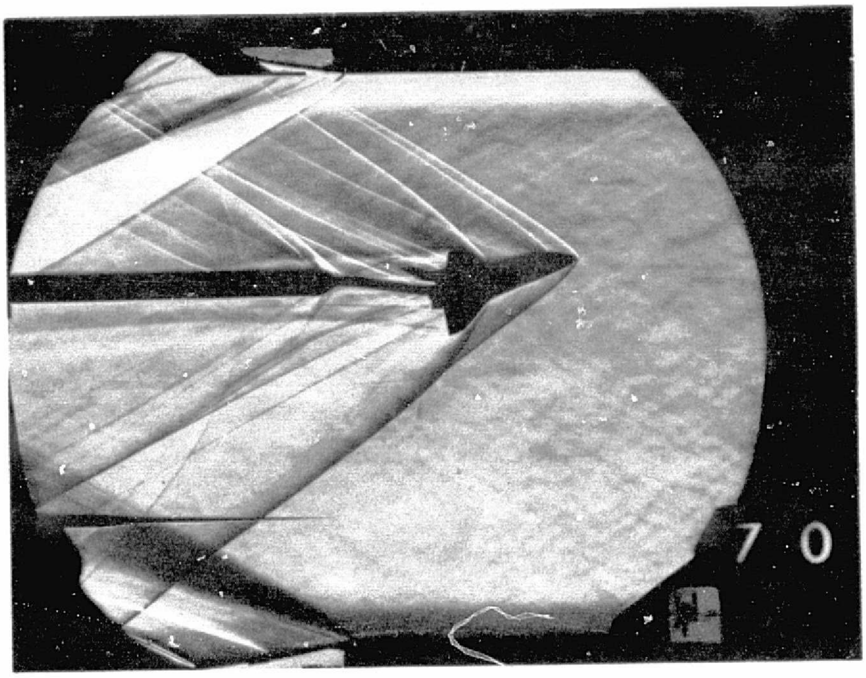


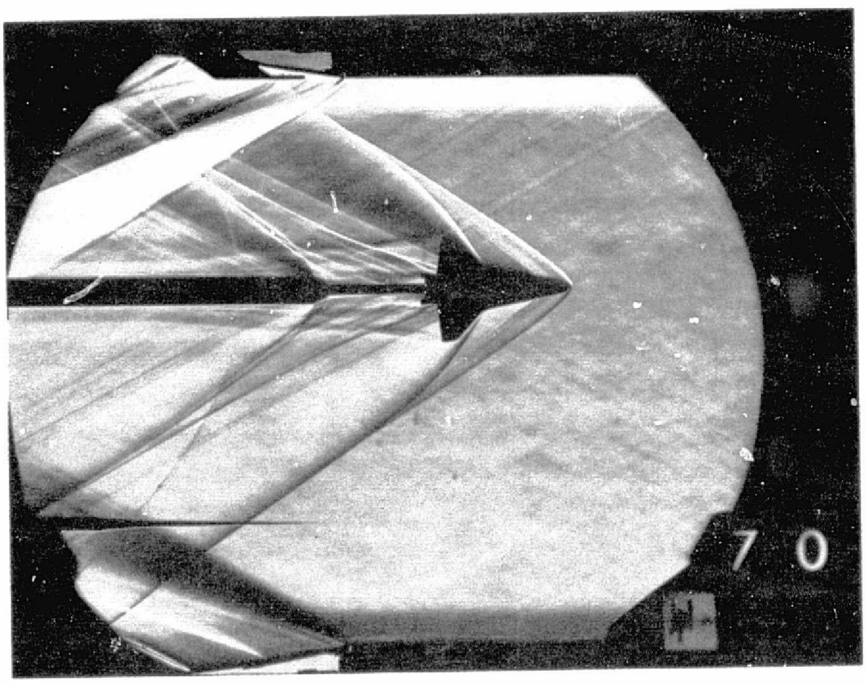


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 12.- Schlieren photographs, $M = 2.0$, $\alpha = 20°$, $h/l = 1.55$.

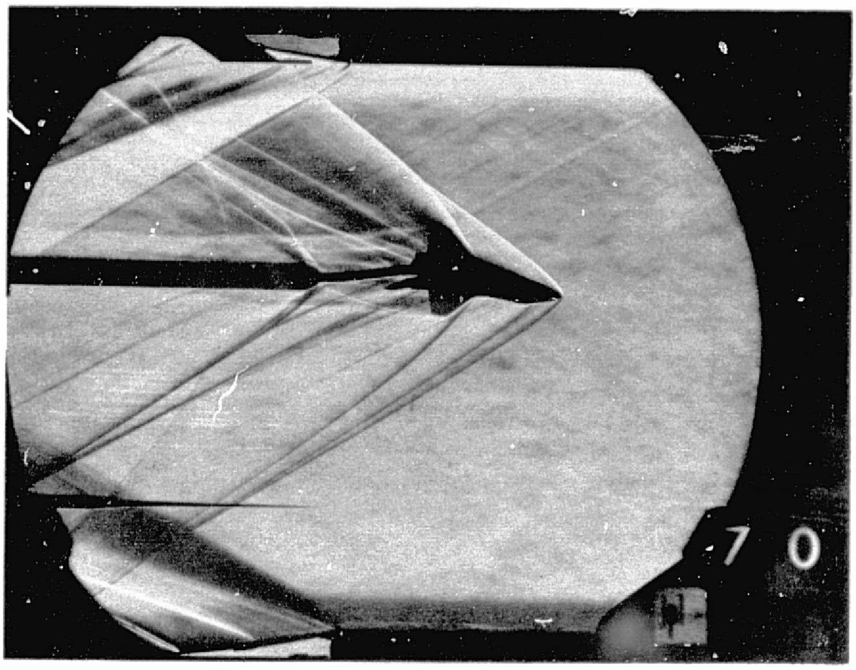




(c) ϕ = 60°

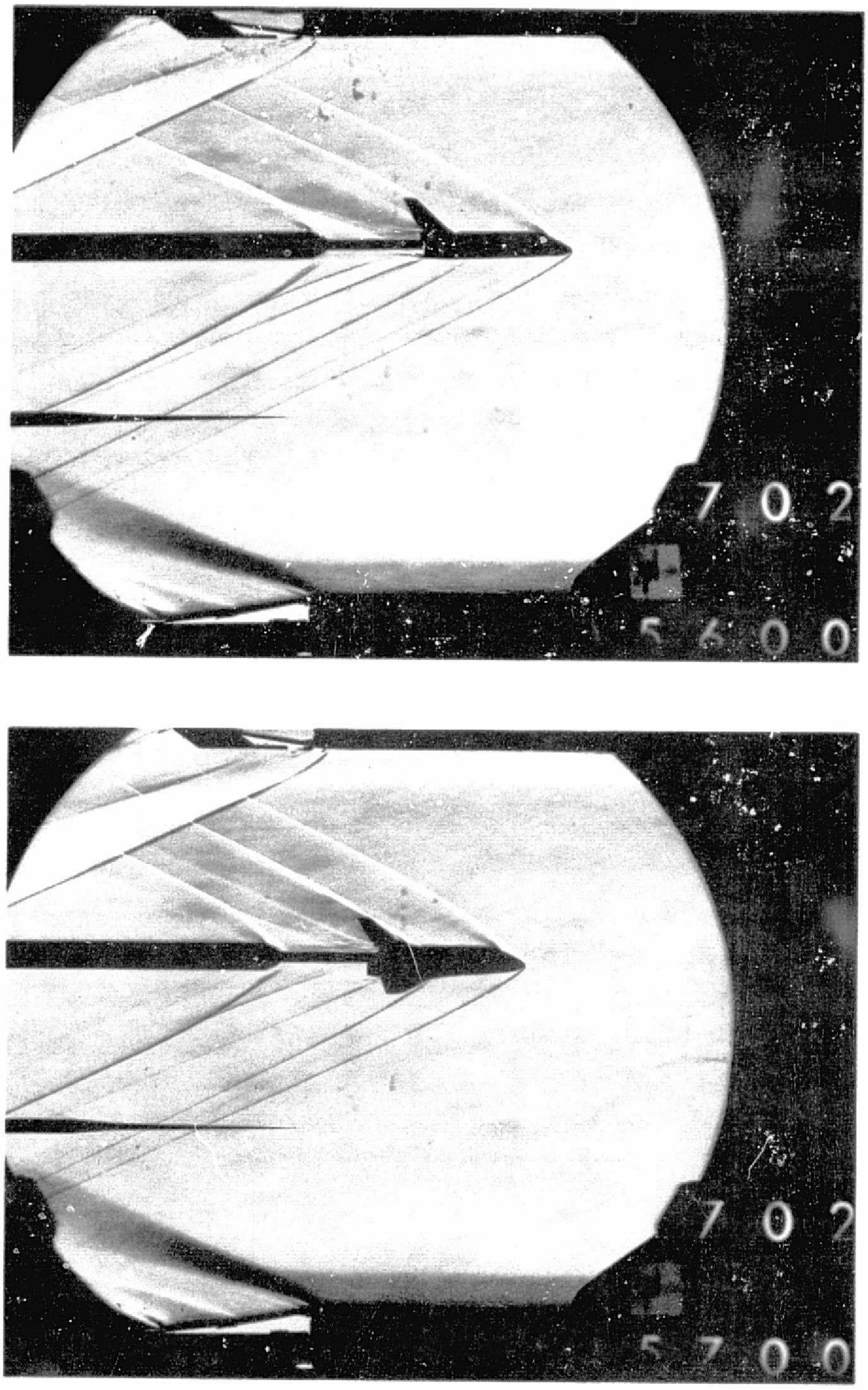
(d) ϕ = 90°

Figure 12.- Continued.



(e) ϕ = 120°

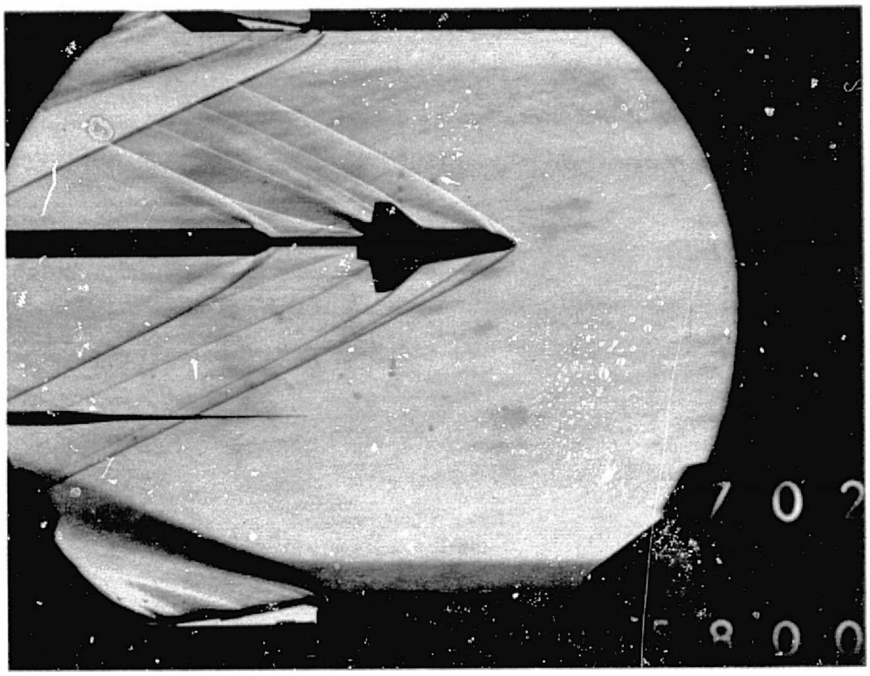
Figure 12.- Concluded.

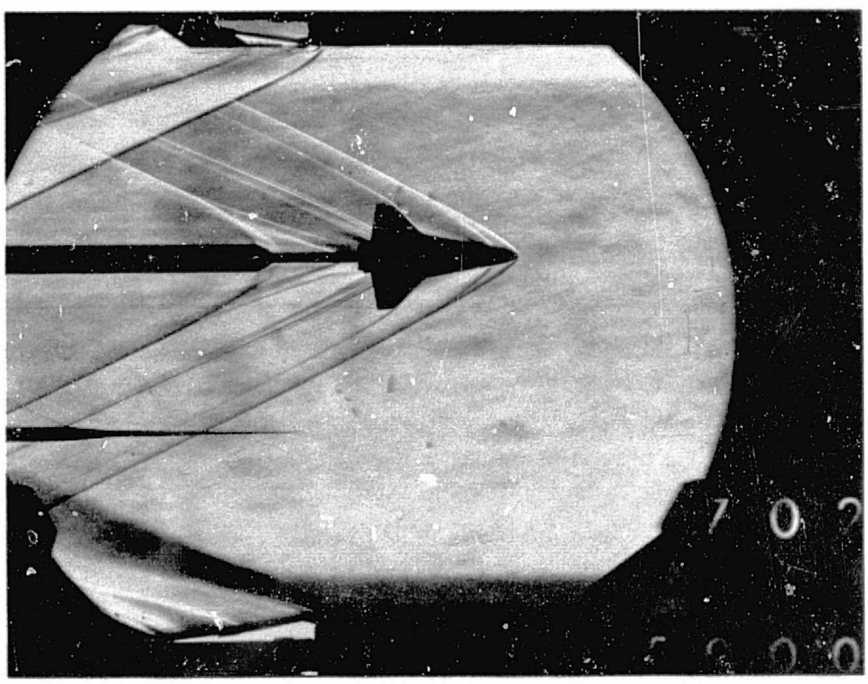


(a) ϕ = 0°

(b) ϕ = 30°

Figure 13.- Schlieren photographs, M = 2.5, α = 0°, h/l = 1.18.

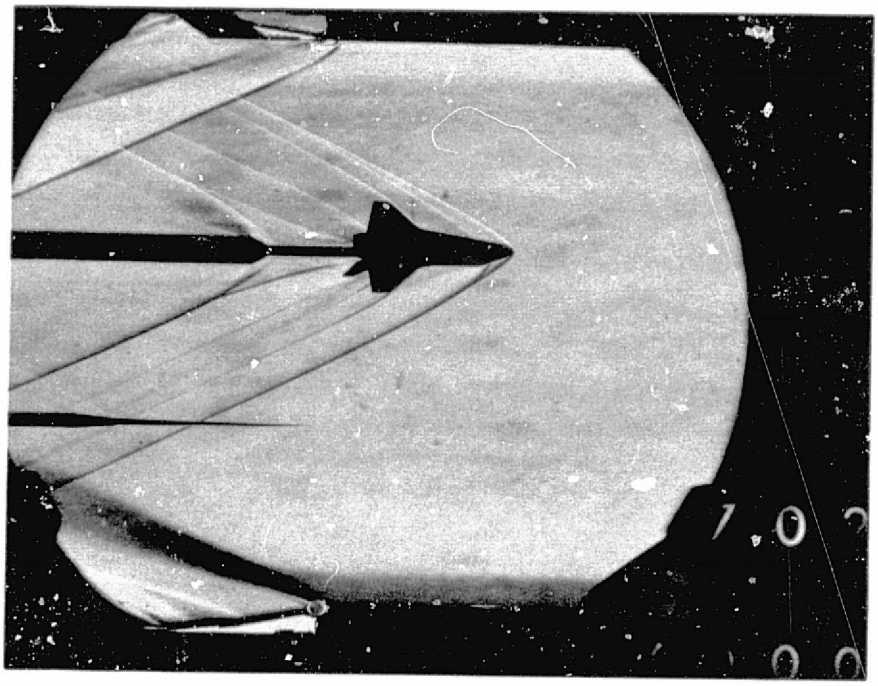




(c) ϕ = 60°

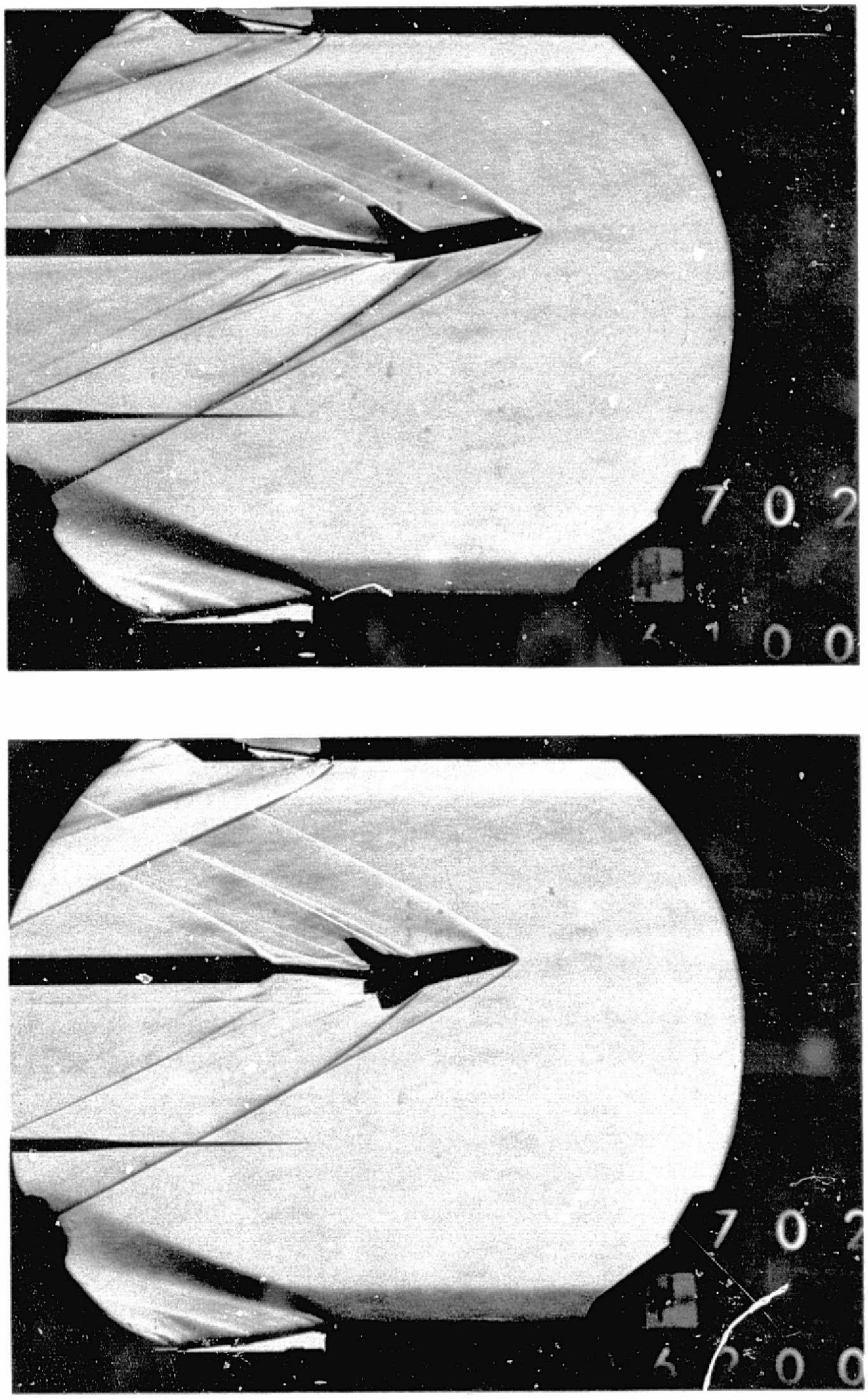
(d) ϕ = 90°

Figure 13.- Continued.



(e) $\phi = 120°$

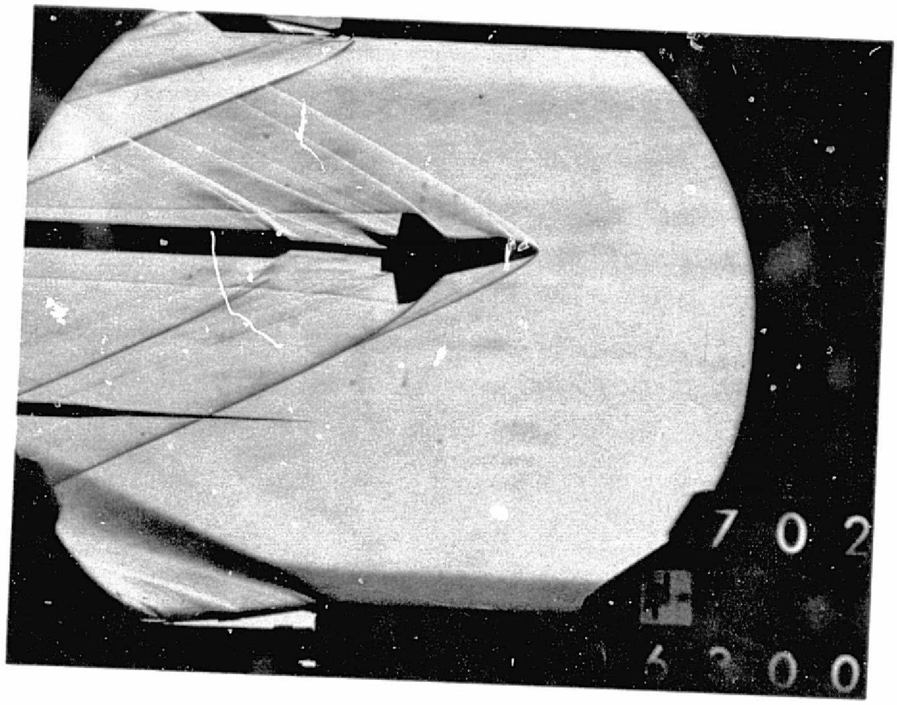
Figure 13.- Concluded.

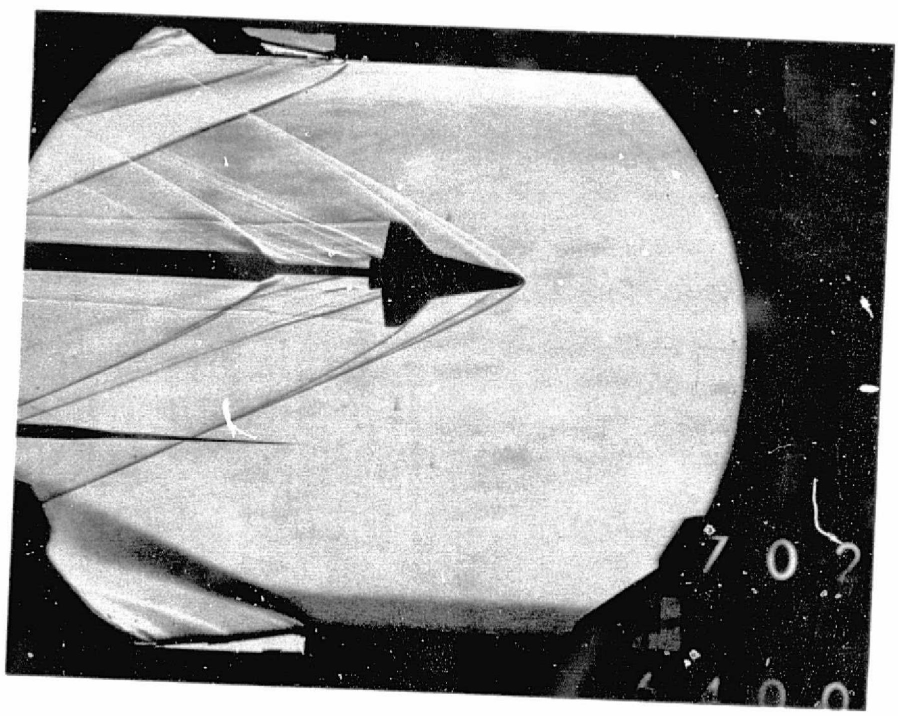


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 14.- Schlieren photographs, $M = 2.5$, $\alpha = 10°$, $h/l = 1.18$.

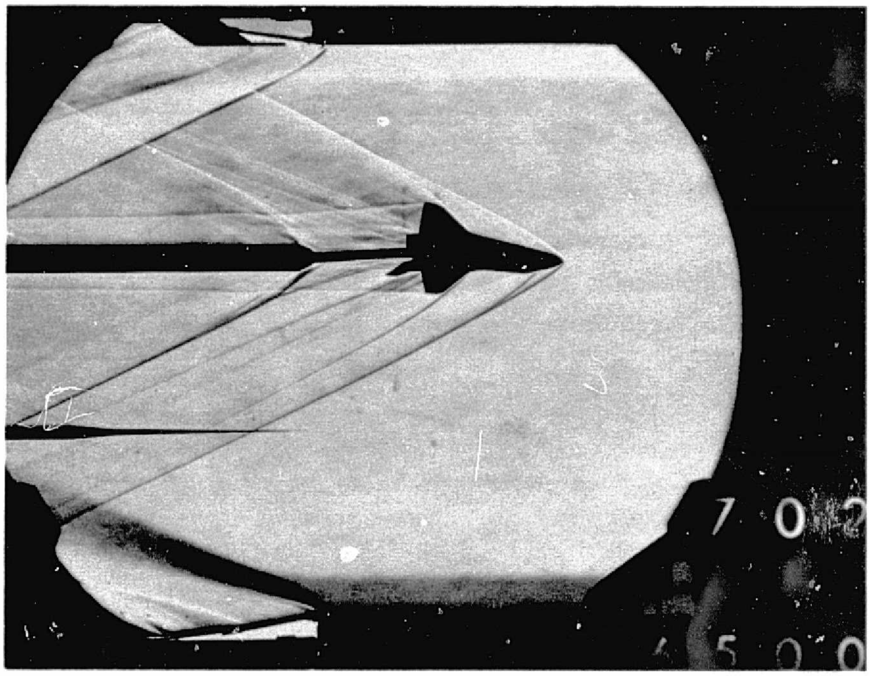




(c) ϕ = 60°

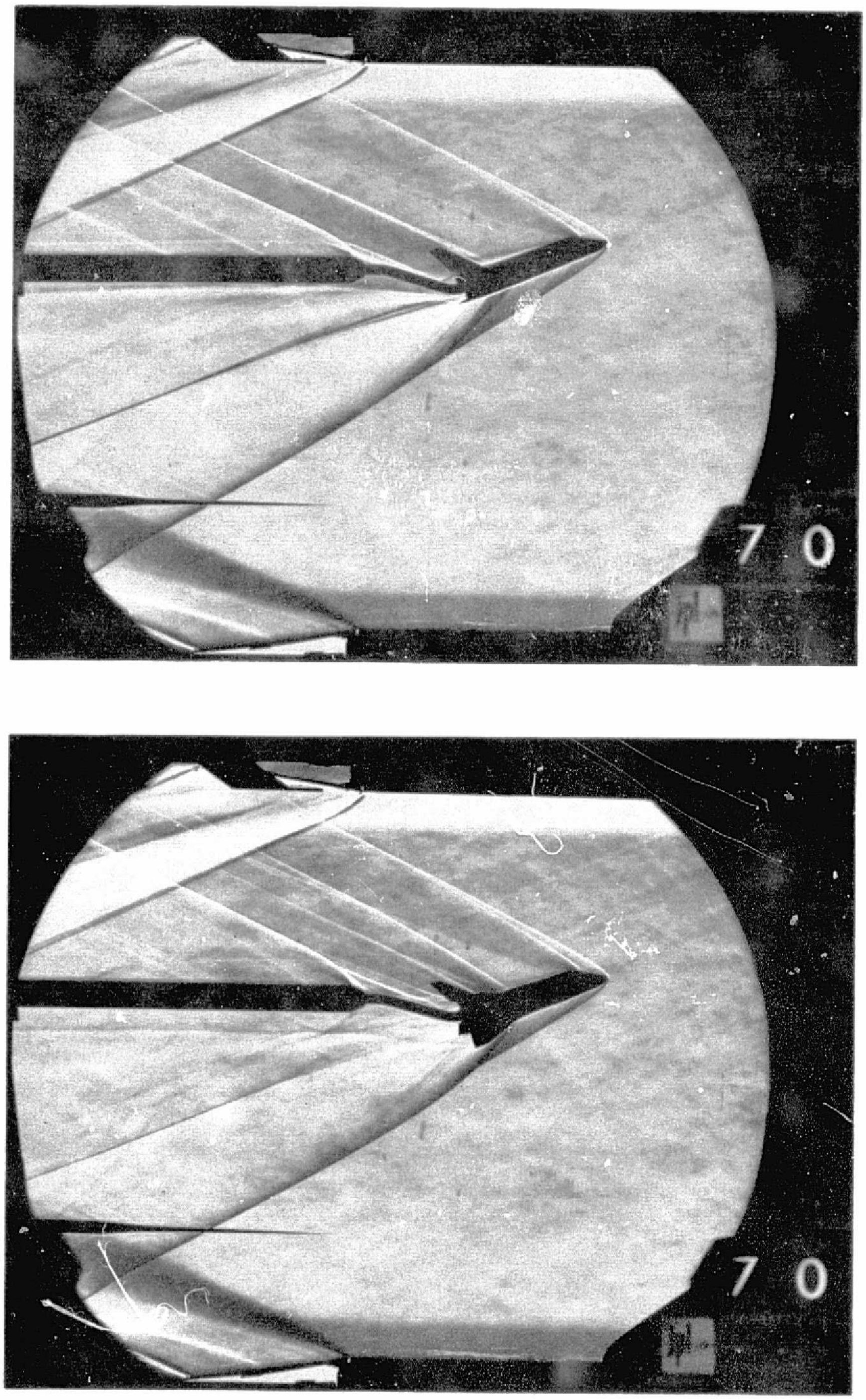
(d) ϕ = 90°

Figure 14.- Continued.



(e) ϕ = 120°

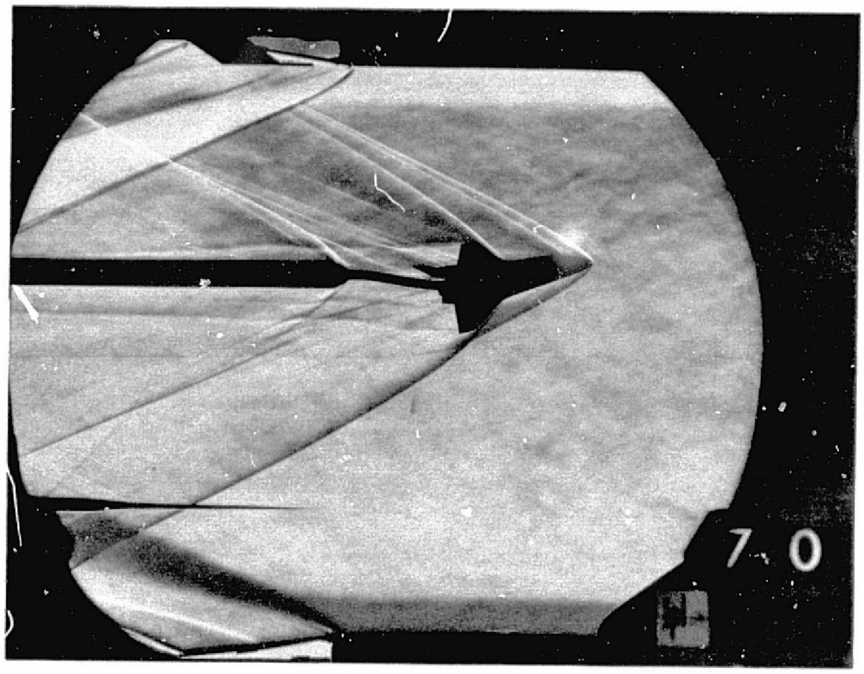
Figure 14.- Concluded.

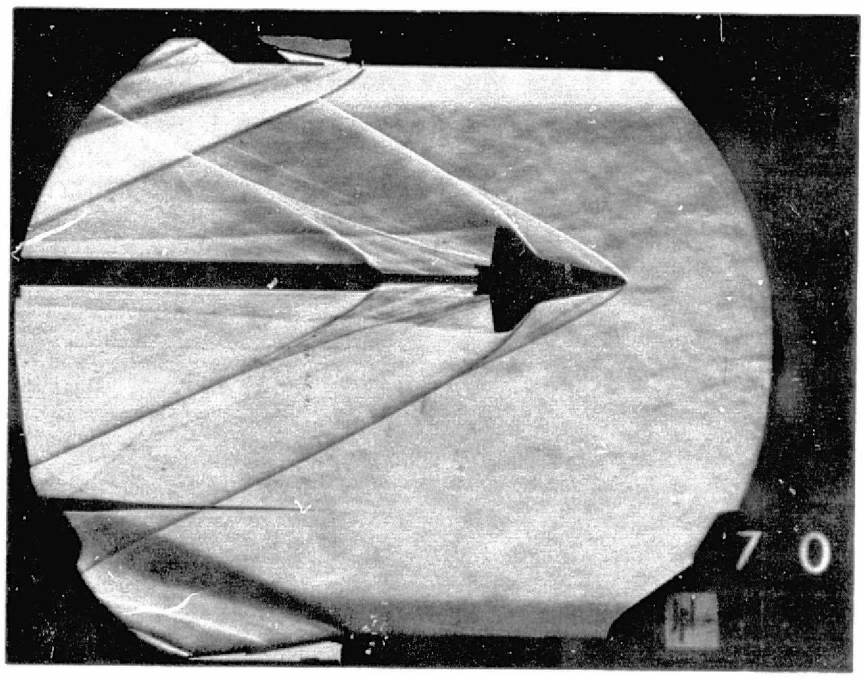


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 15.- Schlieren photographs, $M = 2.5$, $\alpha = 20°$, $h/l = 1.55$.

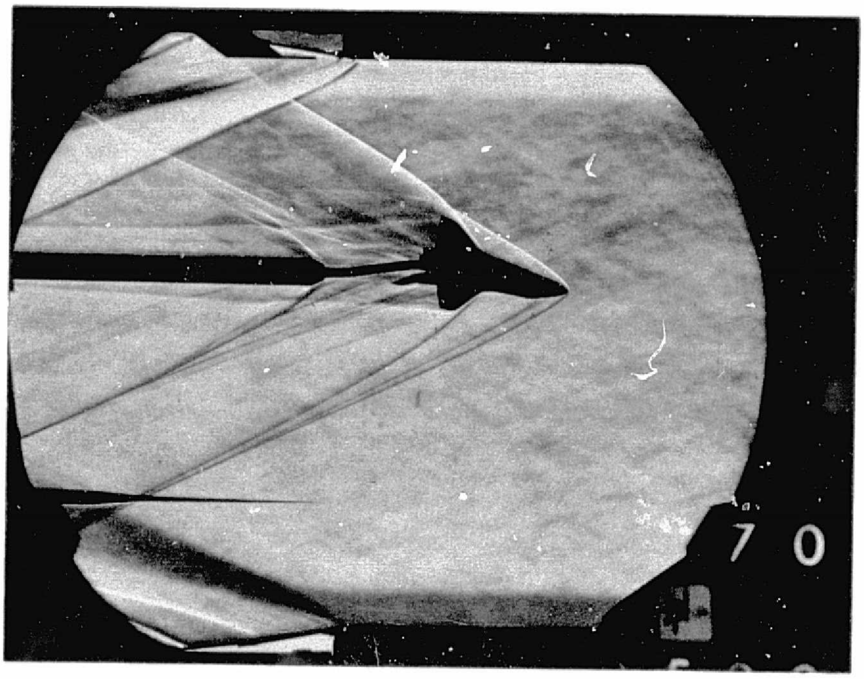




(c) ϕ = 60°

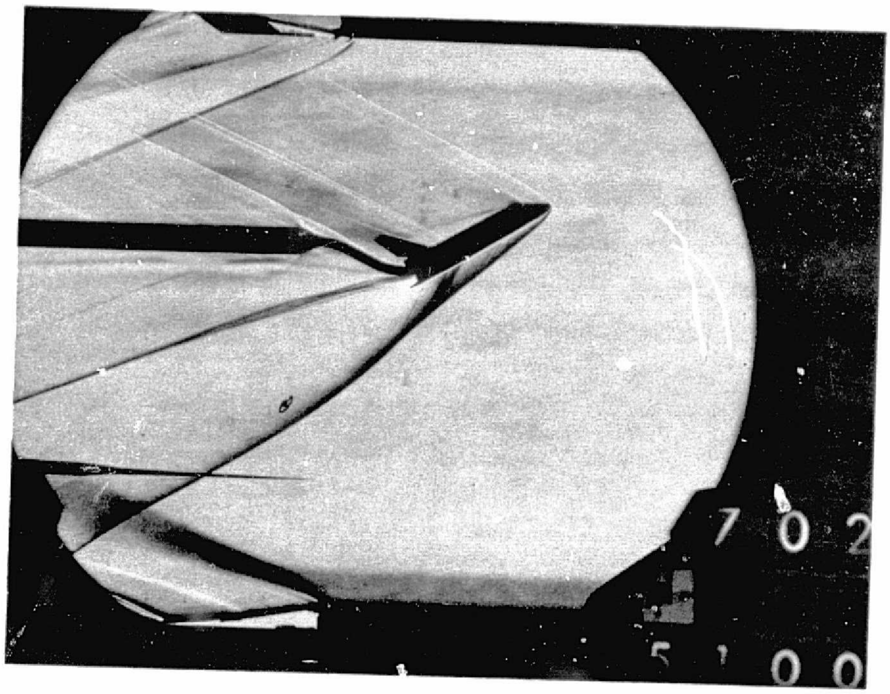
(d) ϕ = 90°

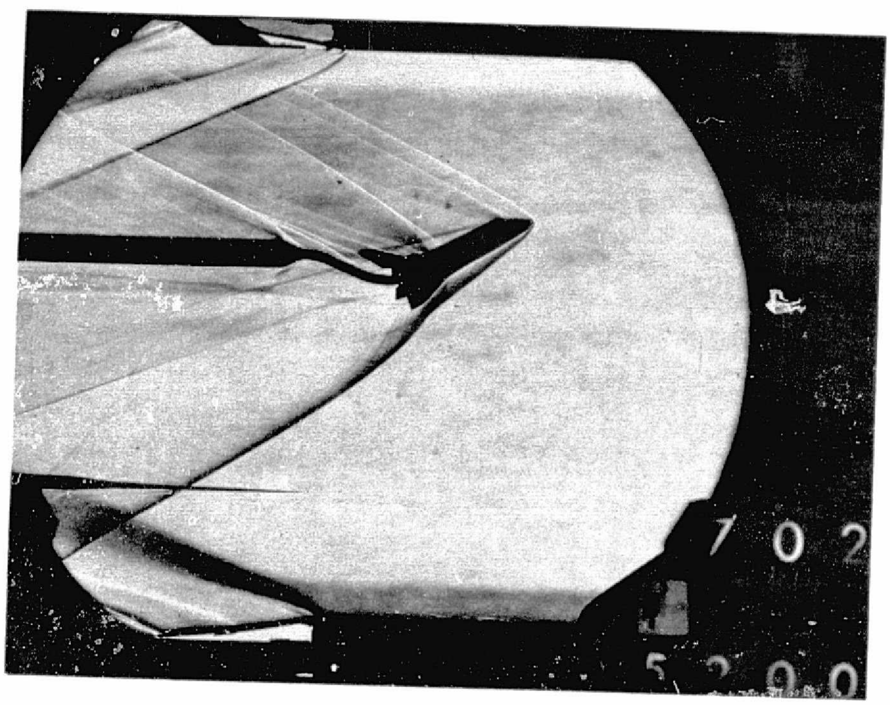
Figure 15.- Continued.



(e) $\phi = 120°$

Figure 15.- Concluded.

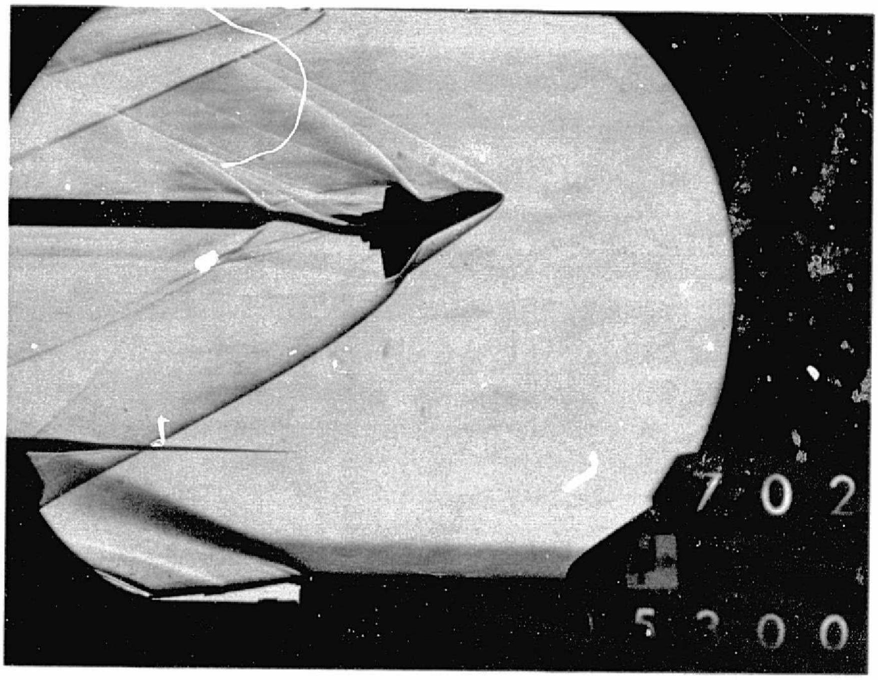


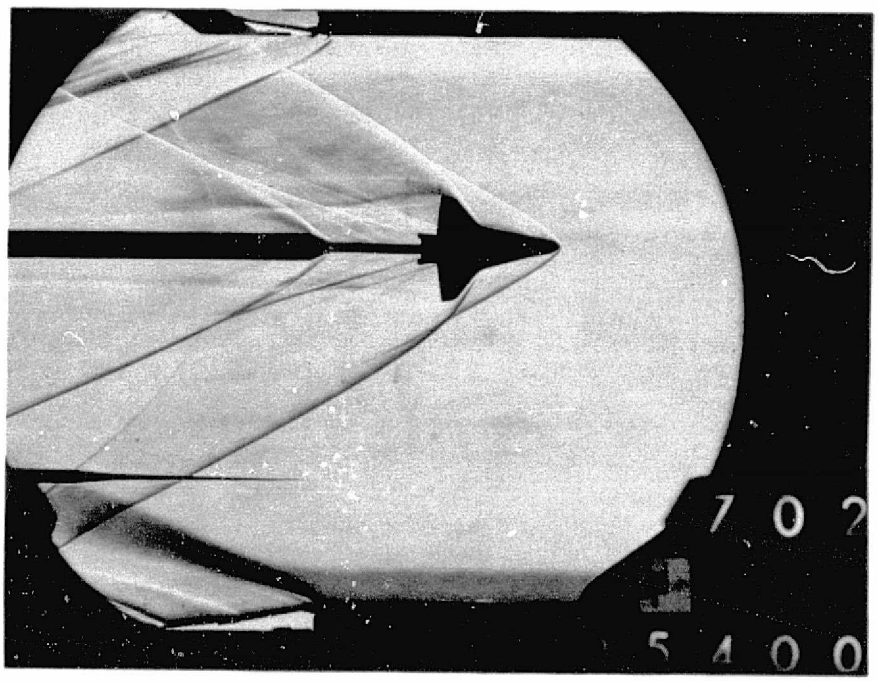


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 16.- Schlieren photographs, $M = 2.5$, $\alpha = 30°$, $h/l = 1.55$.

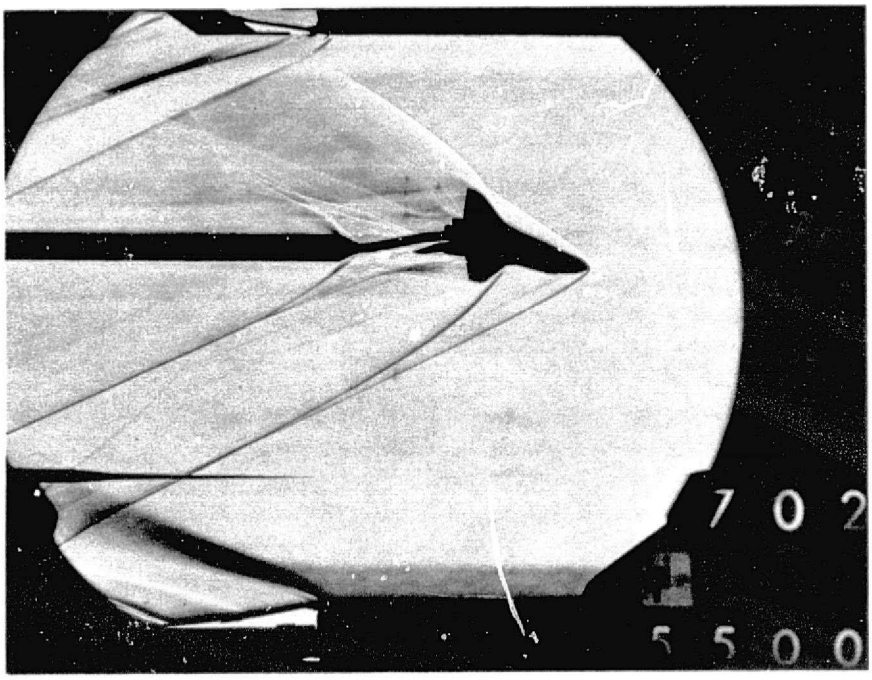




(c) ϕ = 60°

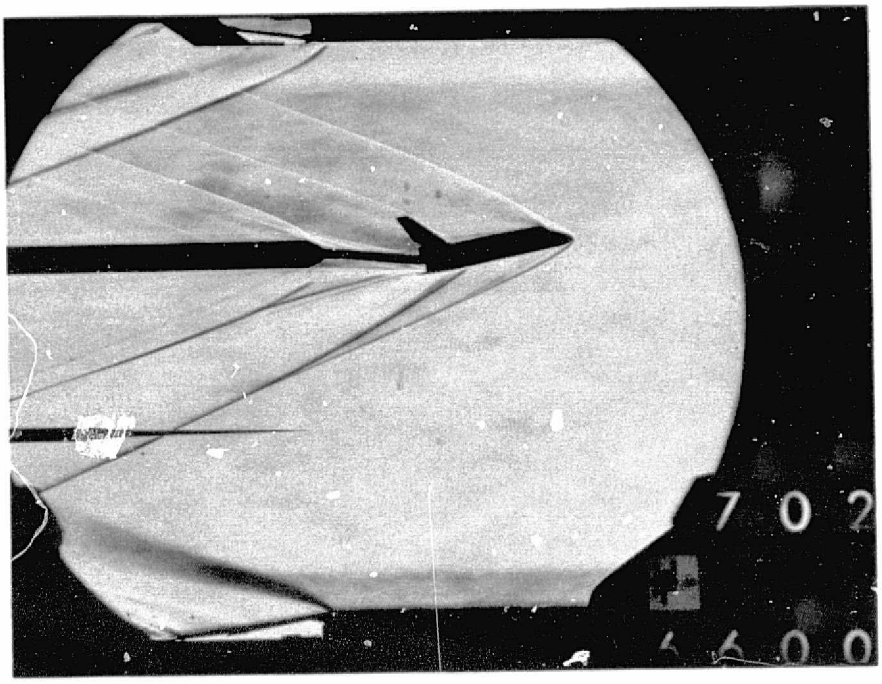
(d) ϕ = 90°

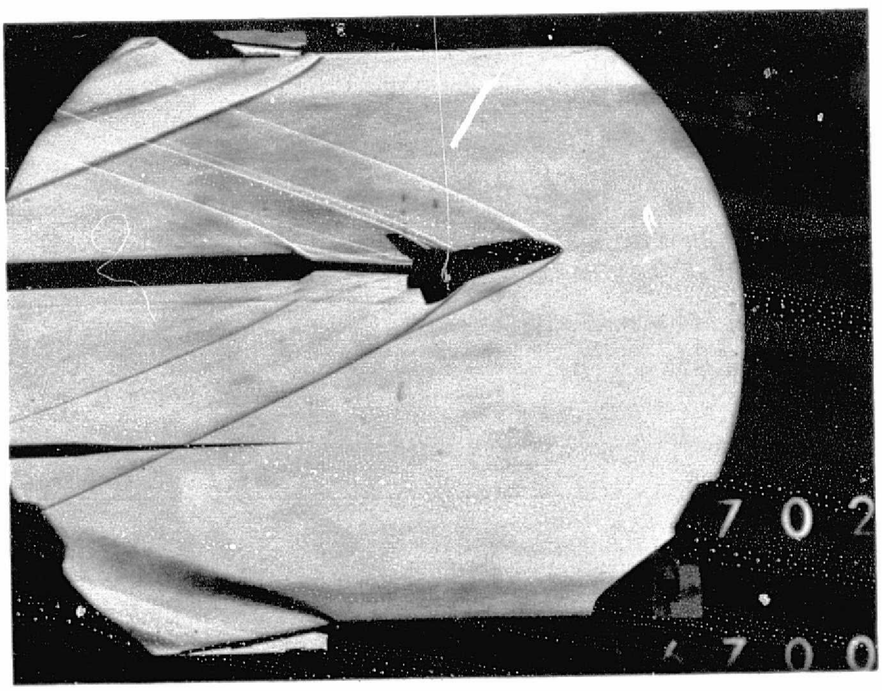
Figure 16.- Continued.



(e) ϕ = 120°

Figure 16.- Concluded.

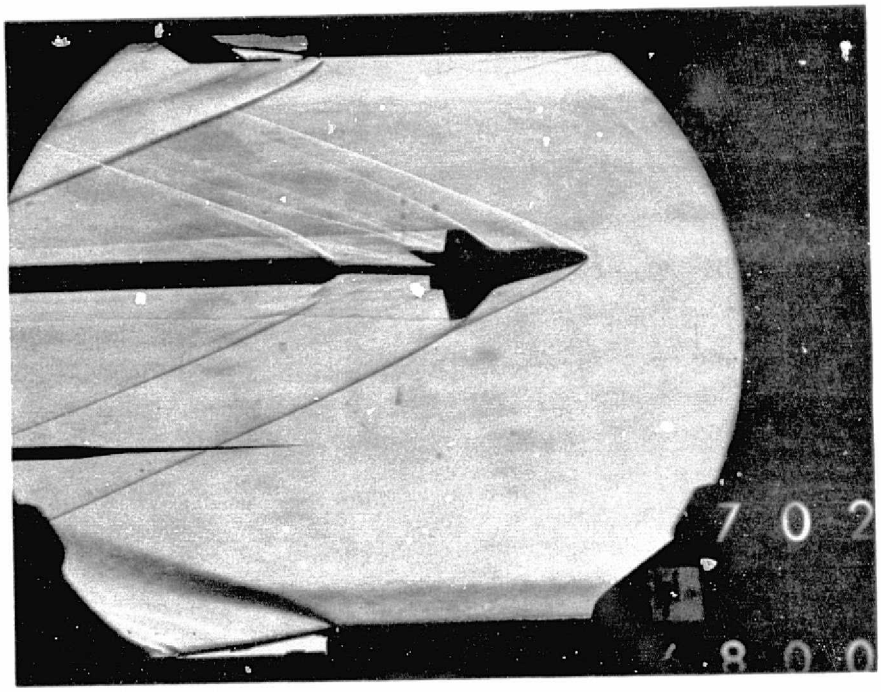


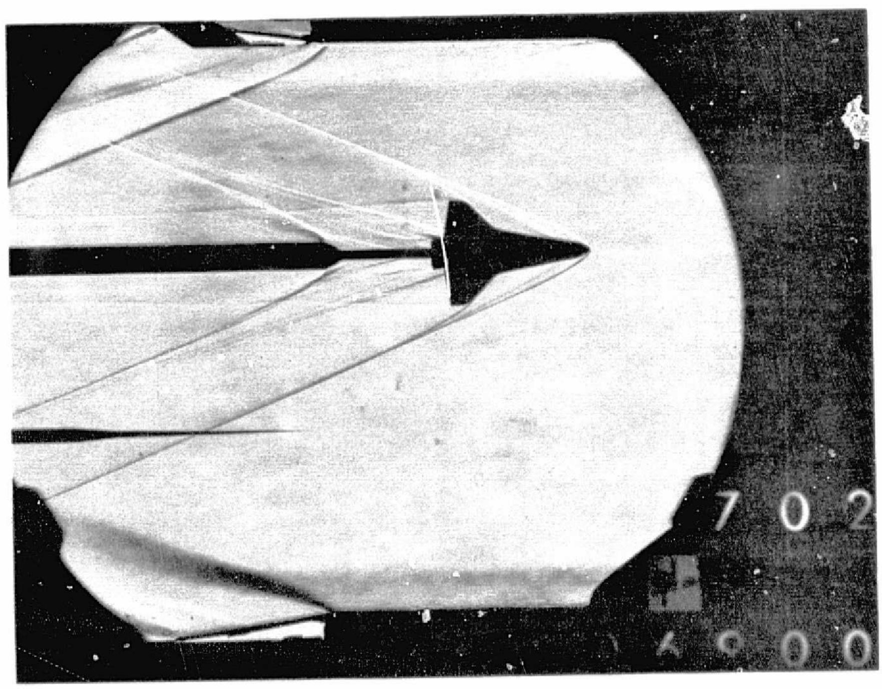


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 17.- Schlieren photographs, $M = 3.0$, $\alpha = 10°$, $h/l = 1.18$.

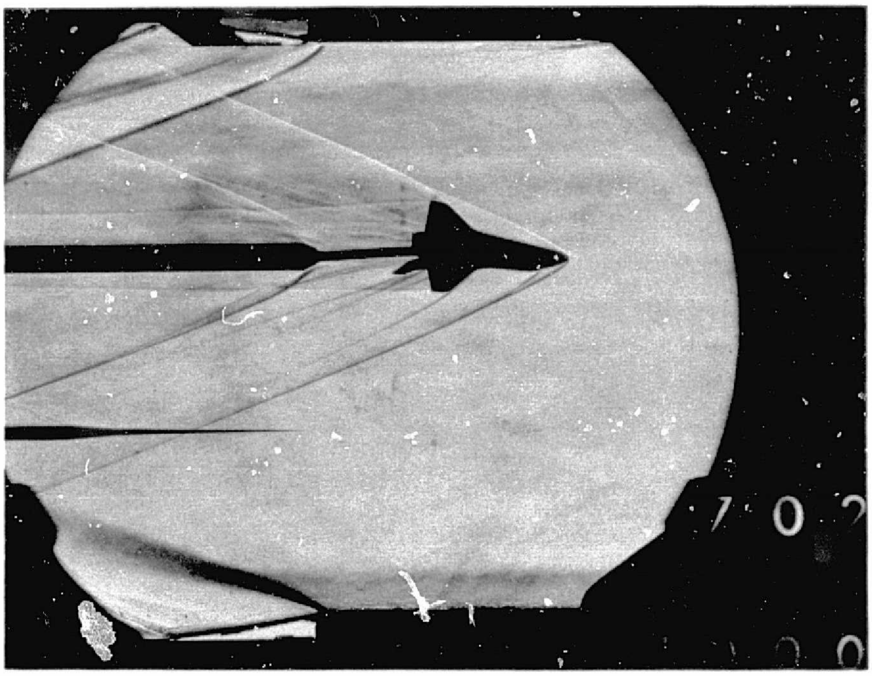




(c) $\phi = 60°$

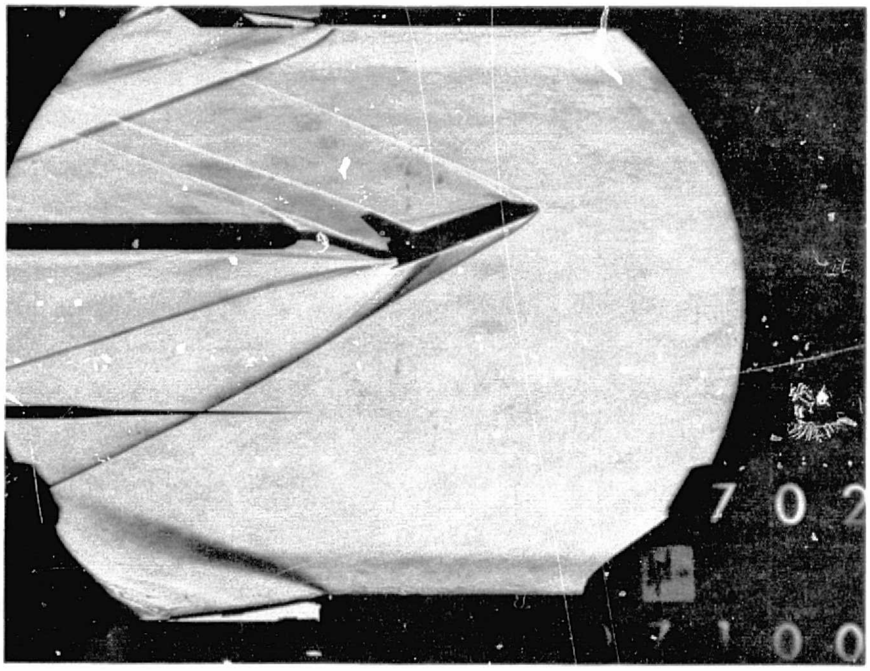
(d) $\phi = 90°$

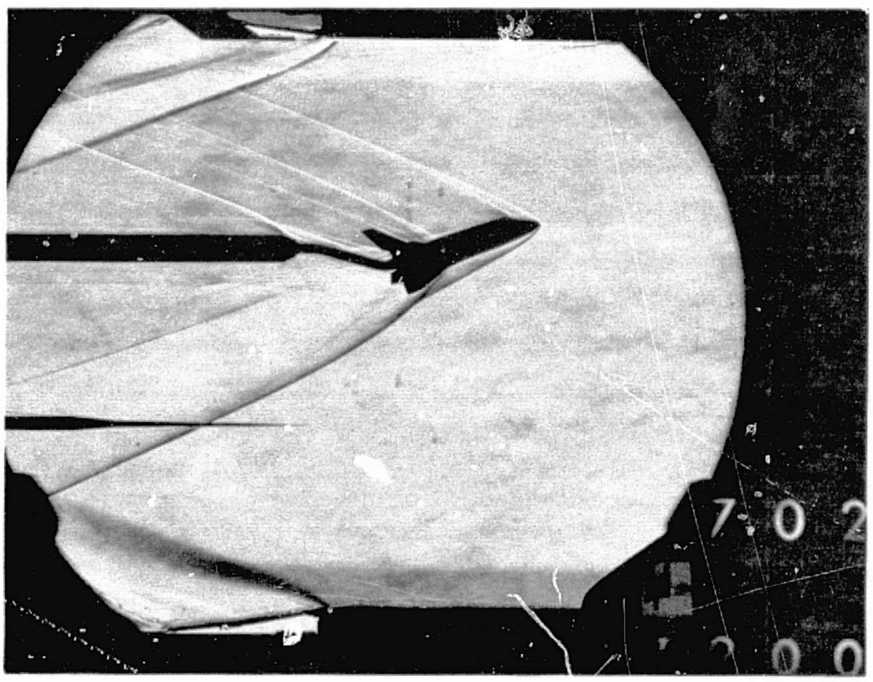
Figure 17.- Continued.



(e) ϕ = 120°

Figure 17.- Concluded.

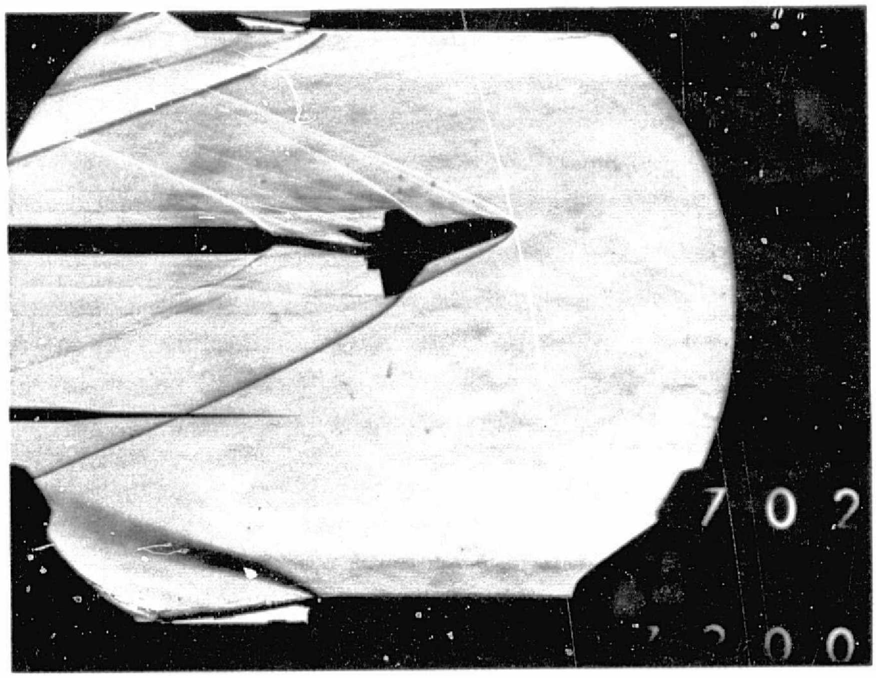


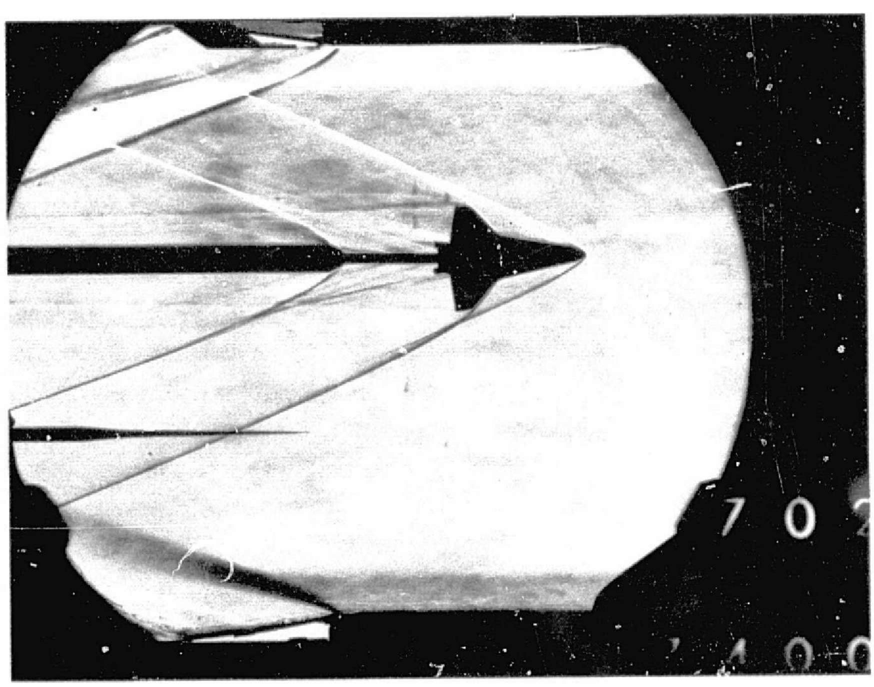


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 18.- Schlieren photographs, $M = 3.0$, $\alpha = 20°$, $h/l = 1.18$.

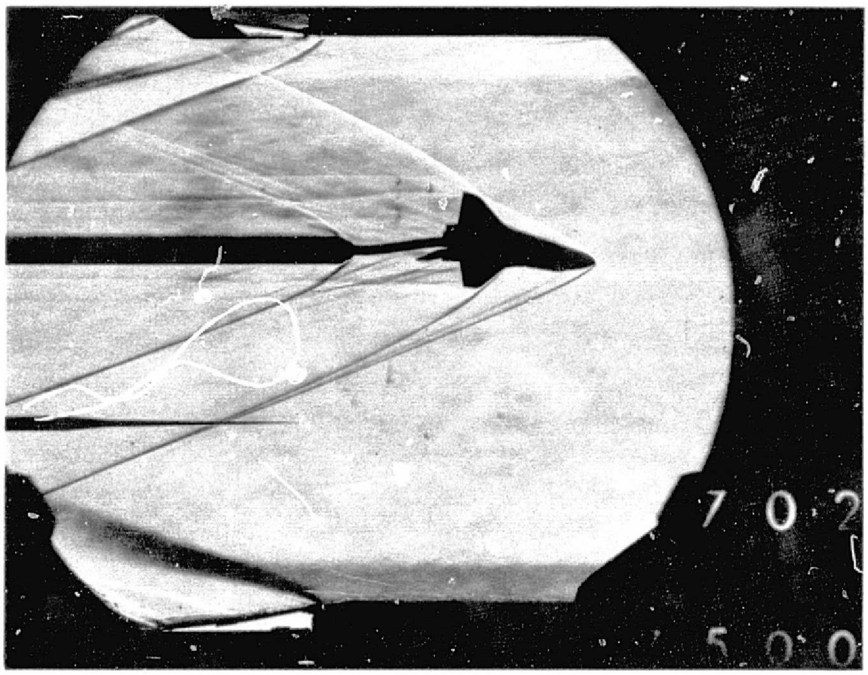




(c) ϕ = 60°

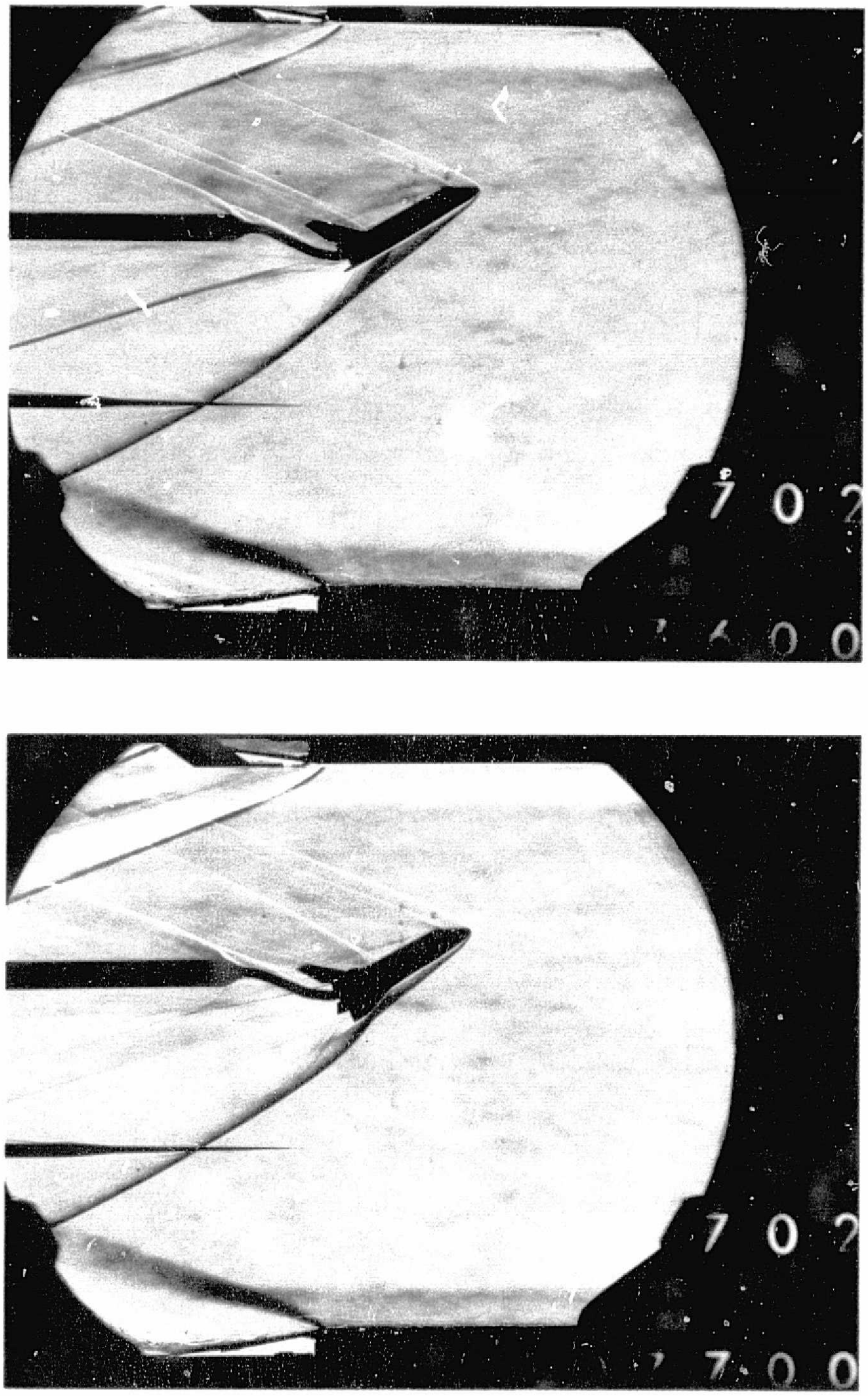
(d) ϕ = 90°

Figure 18.- Continued.



(e) ϕ = 120°

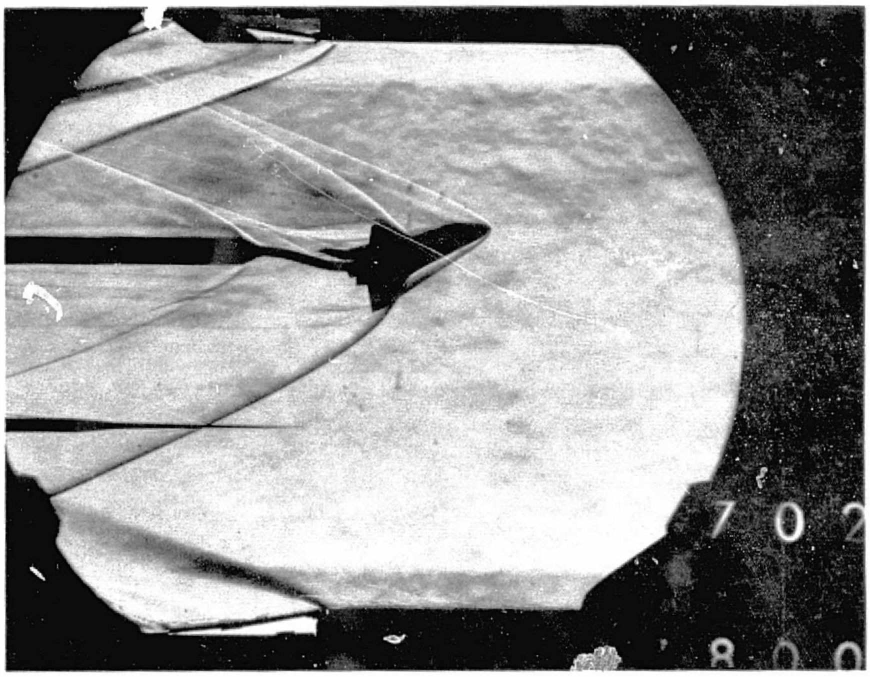
Figure 18.- Concluded.

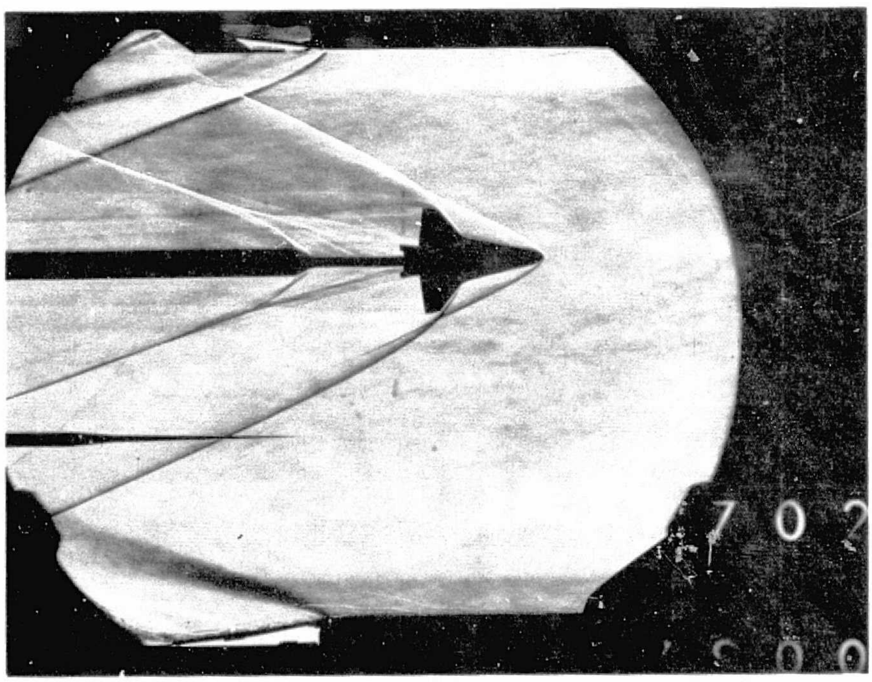


(a) ϕ = 0°

(b) ϕ = 30°

Figure 19.- Schlieren photographs, M = 3.0, α = 30°, h/l = 1.18.

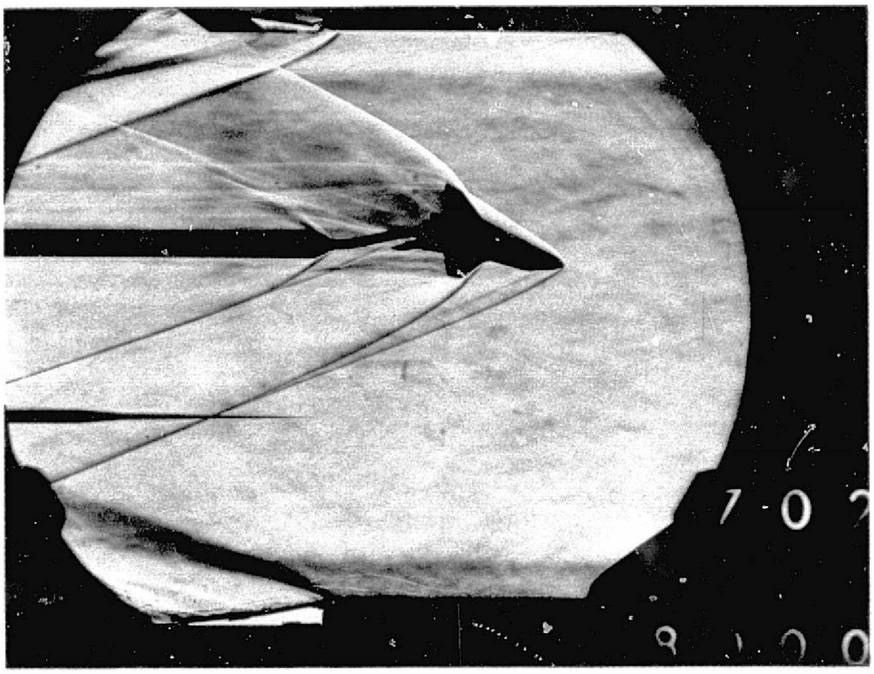




(c) ϕ = 60°

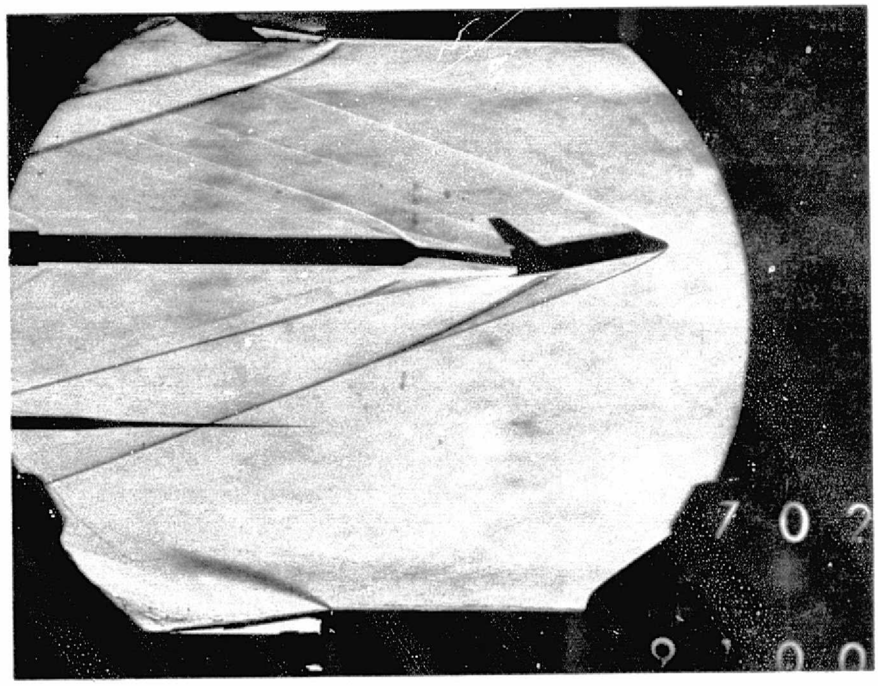
(d) ϕ = 90°

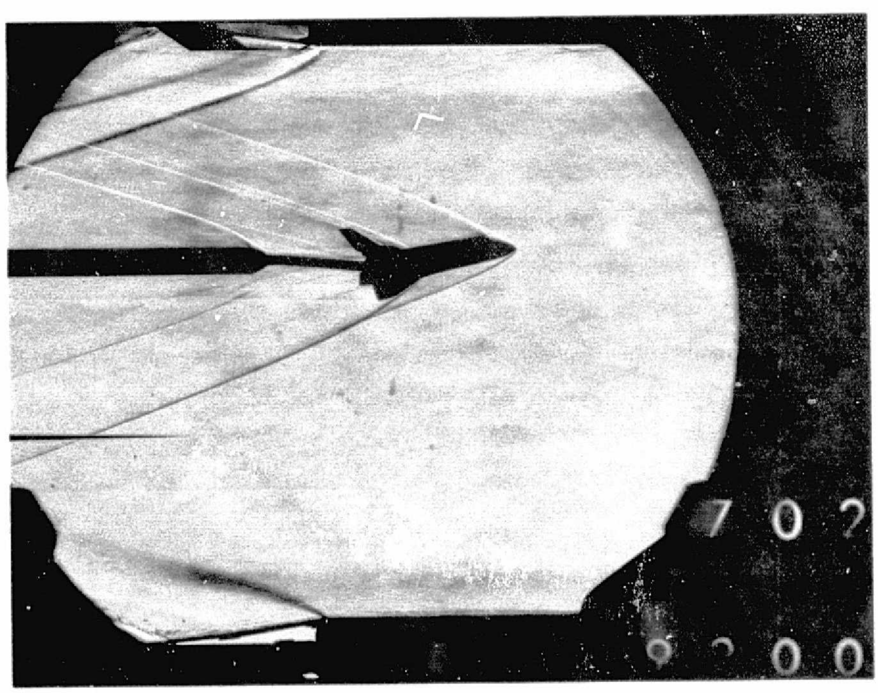
Figure 19.- Continued.



(e) $\phi = 120°$

Figure 19.- Concluded.

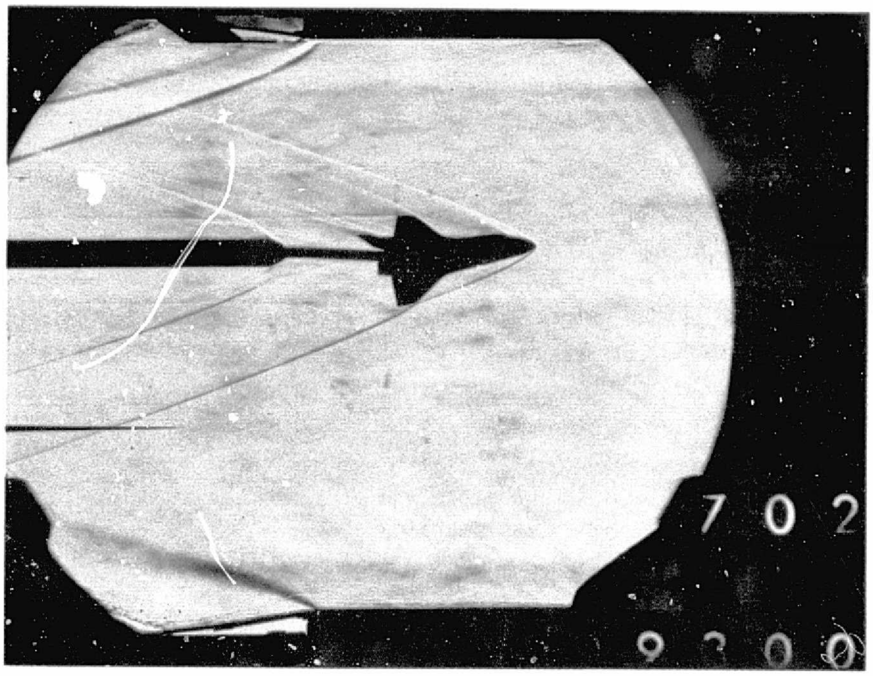


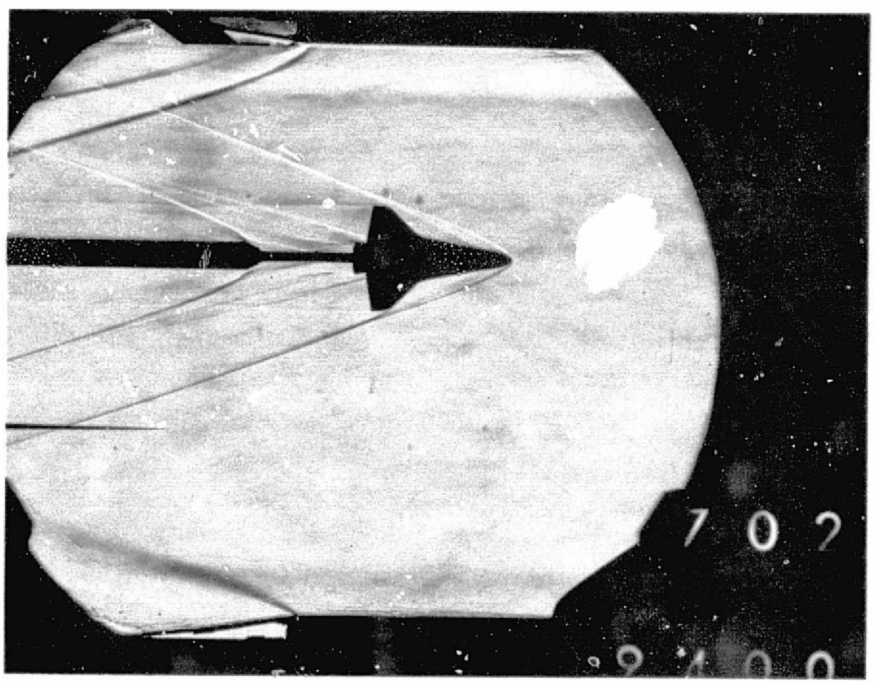


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 20.- Schlieren photographs, $M = 3.5$, $\alpha = 10°$, $h/l = 1.18$.

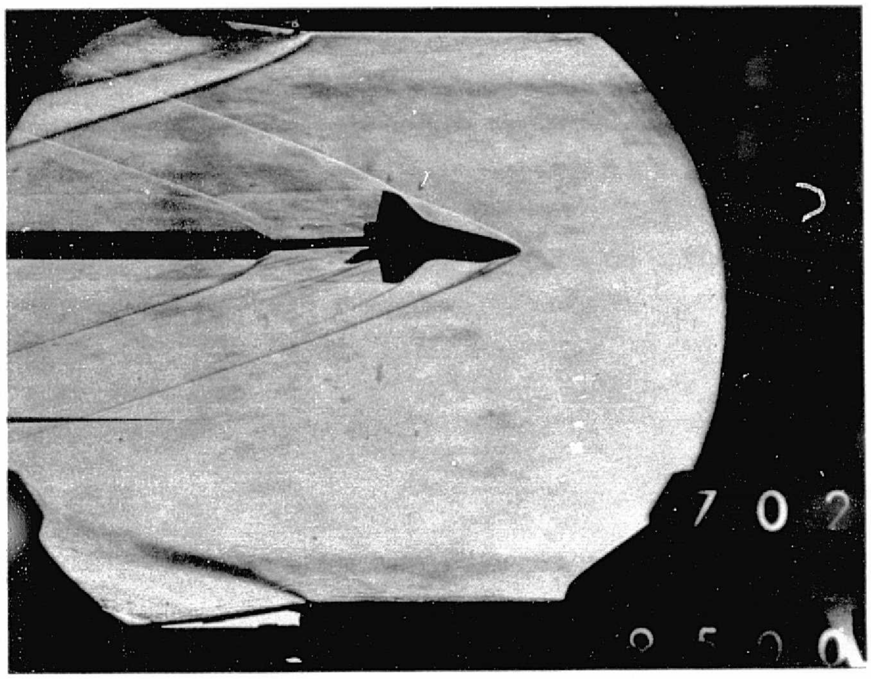




(c) ϕ = 60°

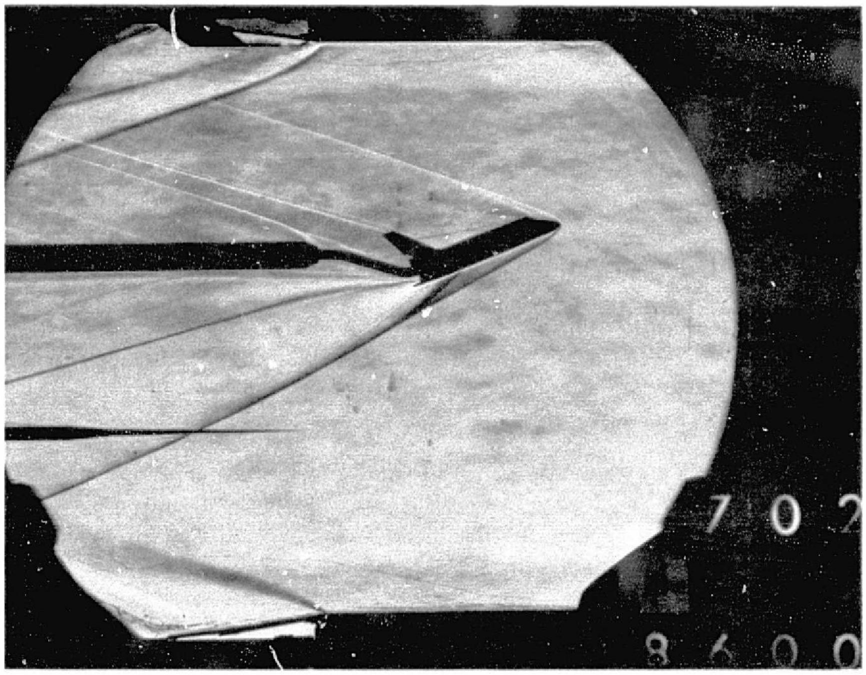
(d) ϕ = 90°

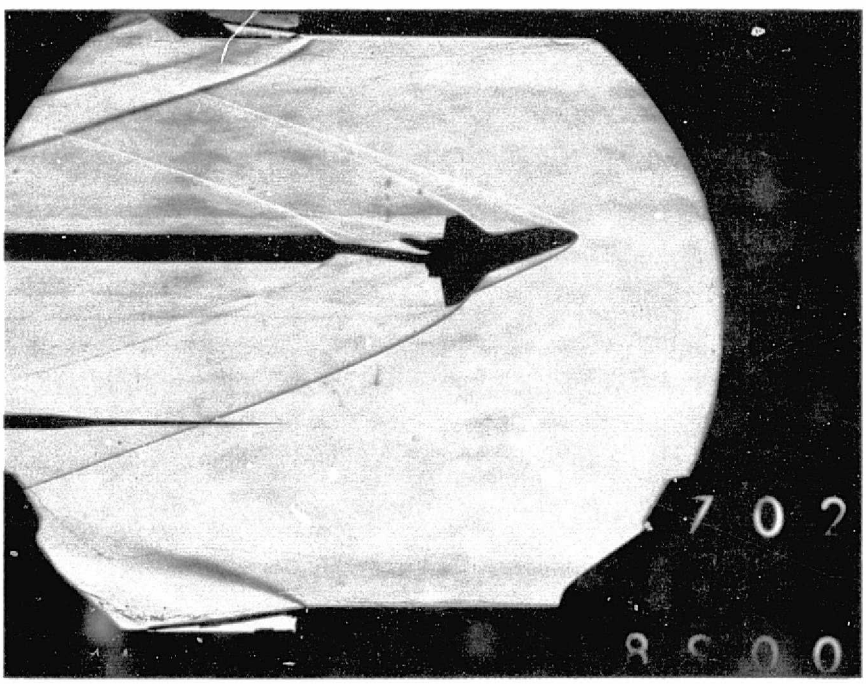
Figure 20.- Continued.



(e) $\phi = 120°$

Figure 20.- Concluded.

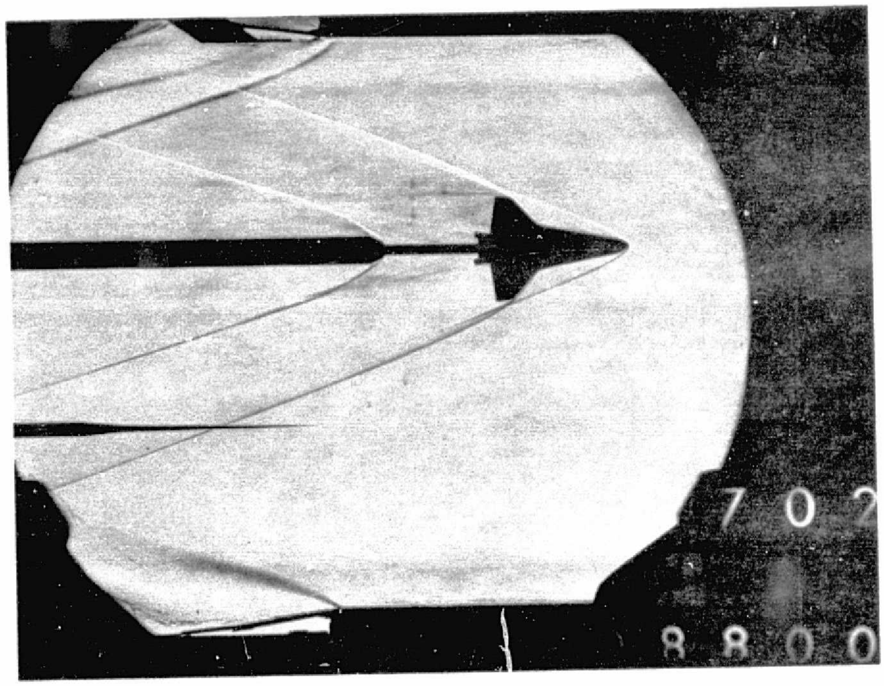


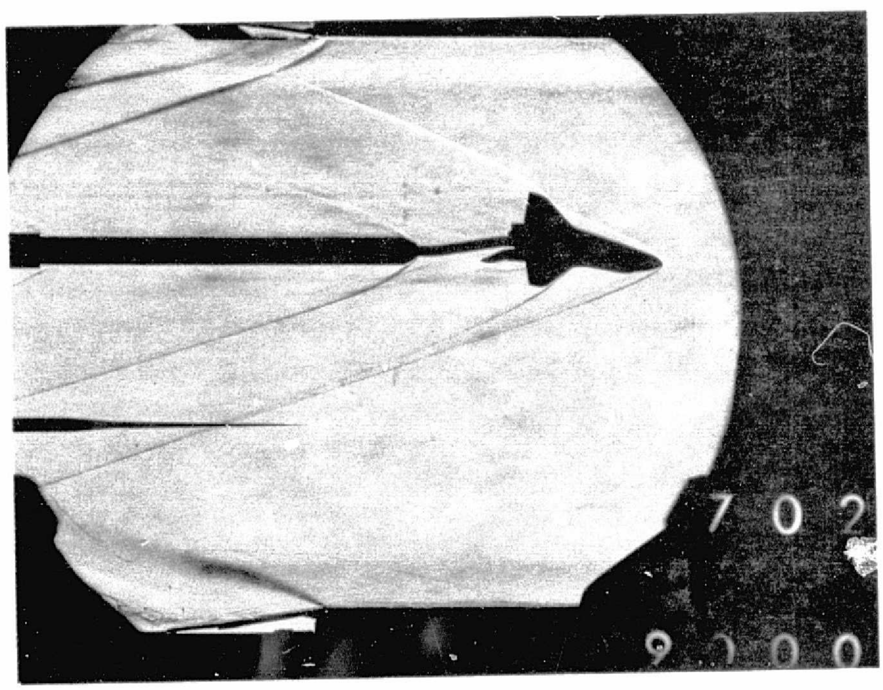


(a) $\phi = 0°$

(b) $\phi = 60°$

Figure 21.- Schlieren photographs, $M = 3.5$, $\alpha = 20°$, $h/l = 1.18$.

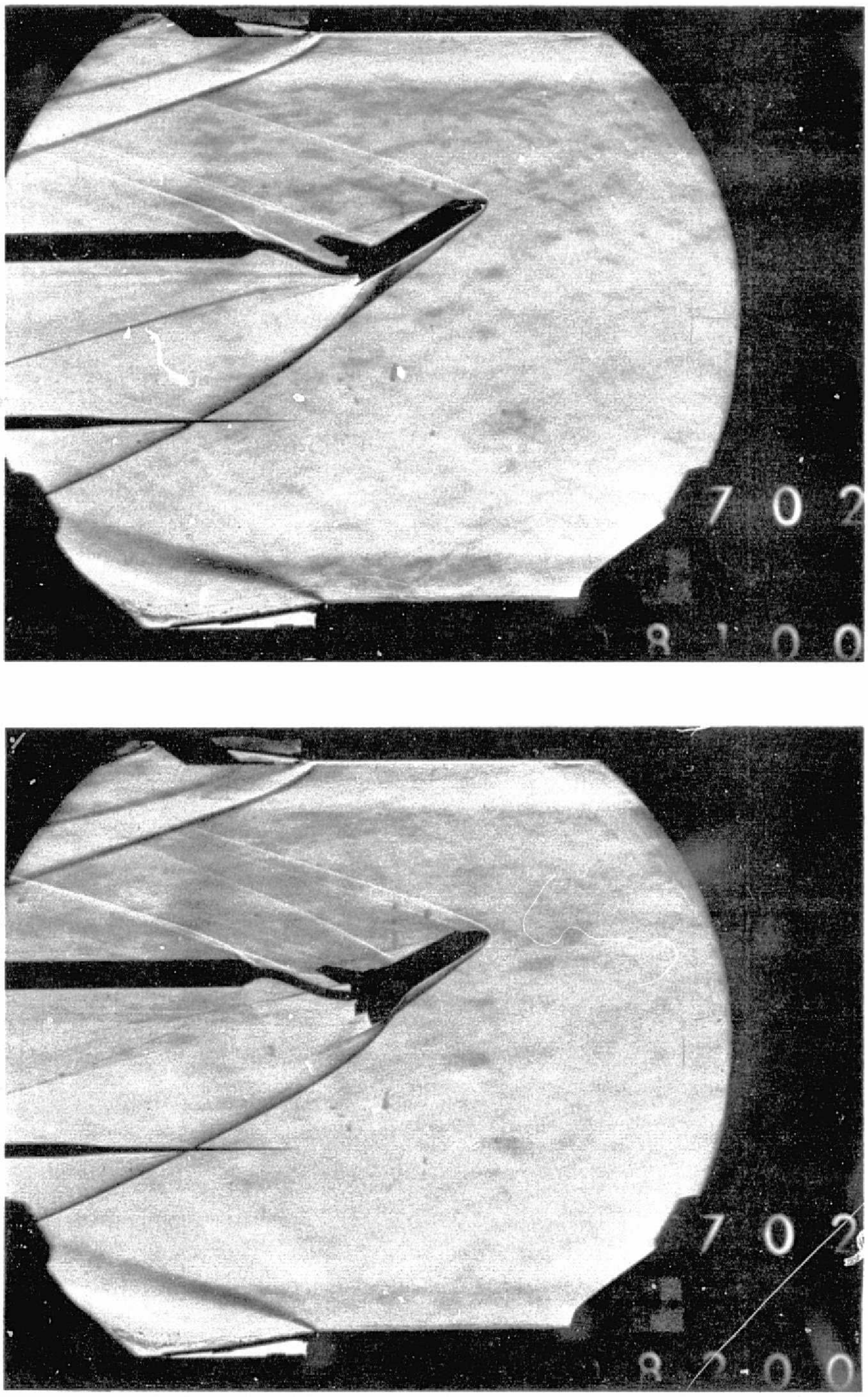




(c) ϕ = 90°

(d) ϕ = 120°

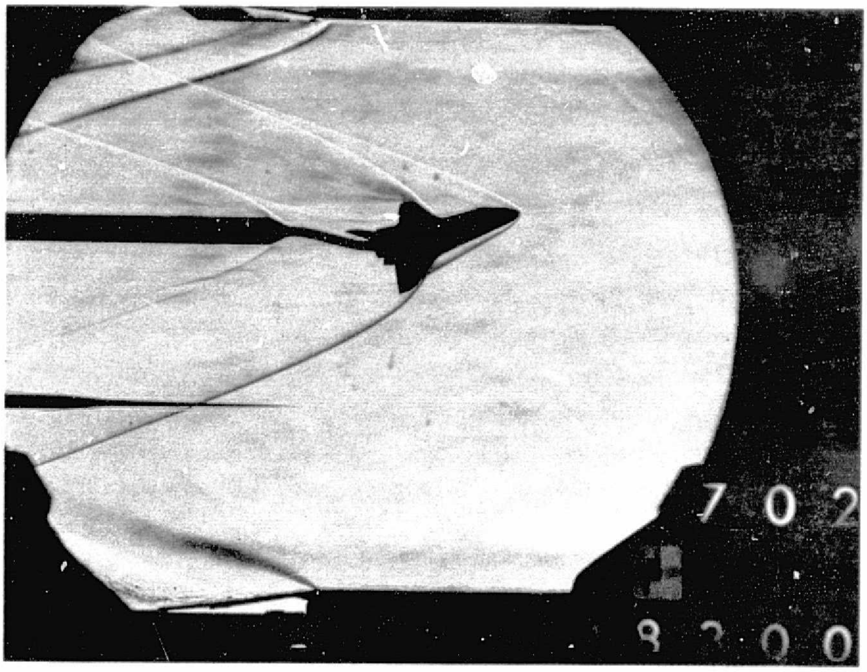
Figure 21.- Concluded.

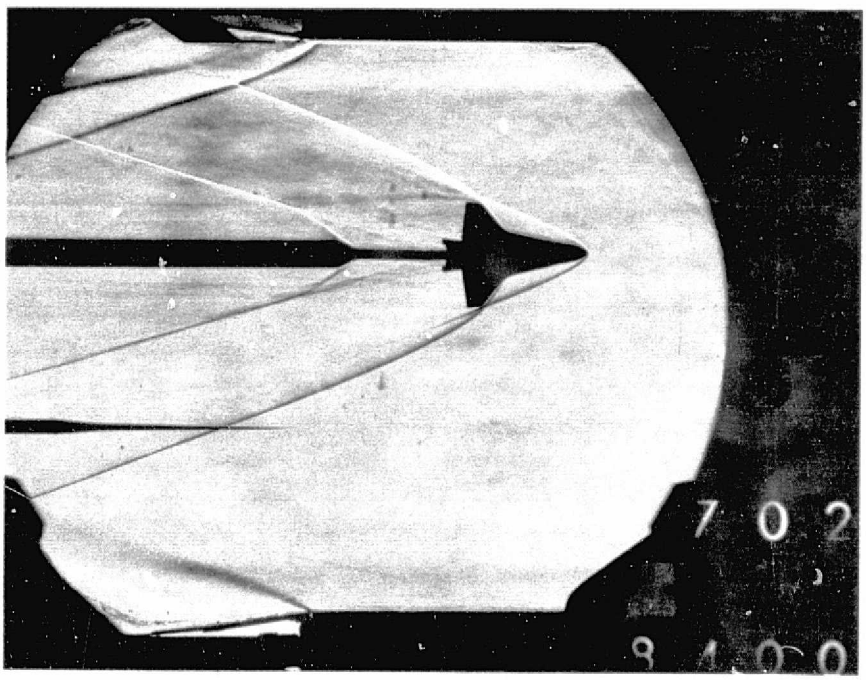


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 22.- Schlieren photographs, $M = 3.5$, $\alpha = 30°$, $h/l = 1.18$.

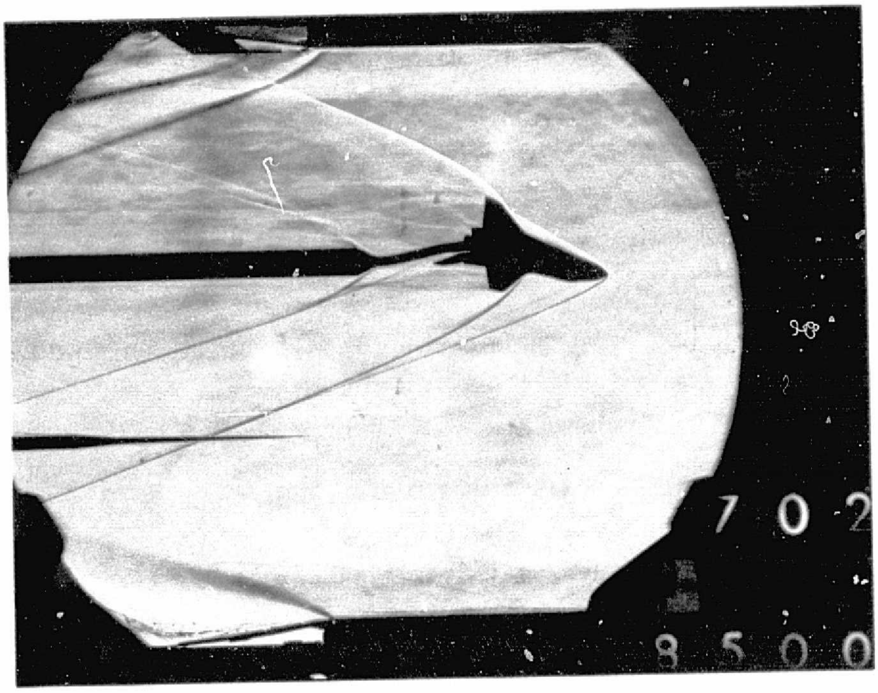




(c) ϕ = 60°

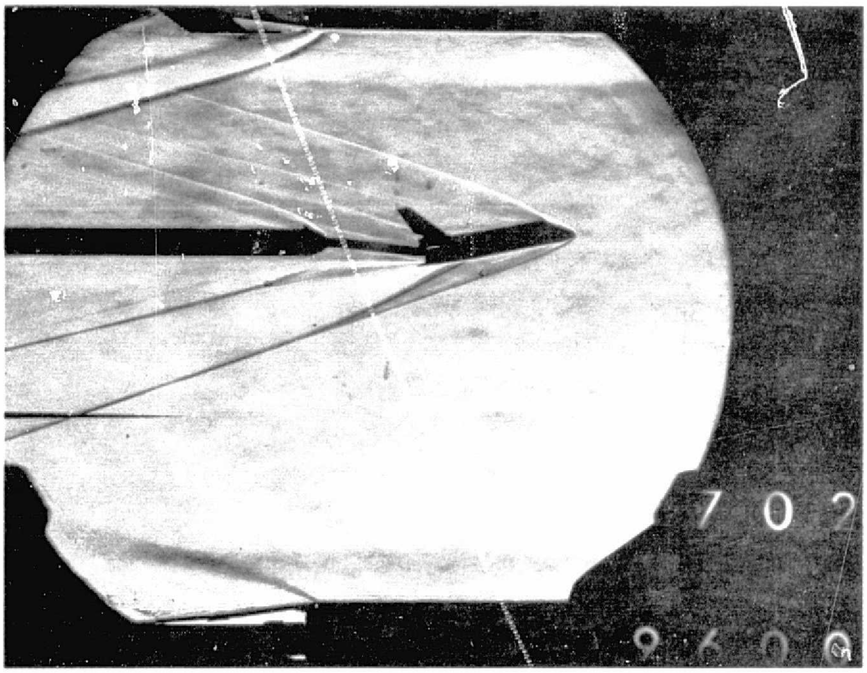
(d) ϕ = 90°

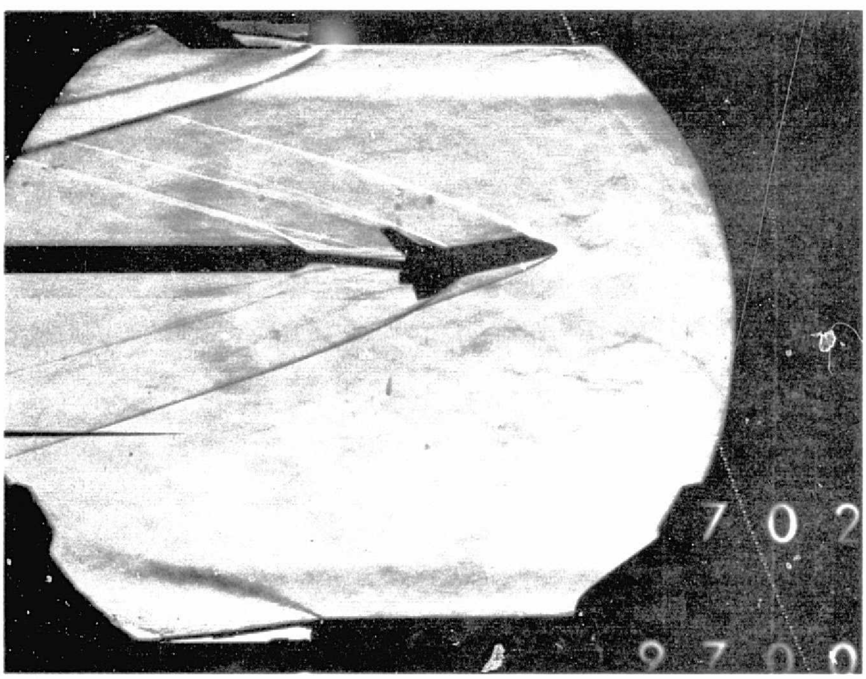
Figure 22.- Continued.



(e) $\phi = 120°$

Figure 22.- Concluded.

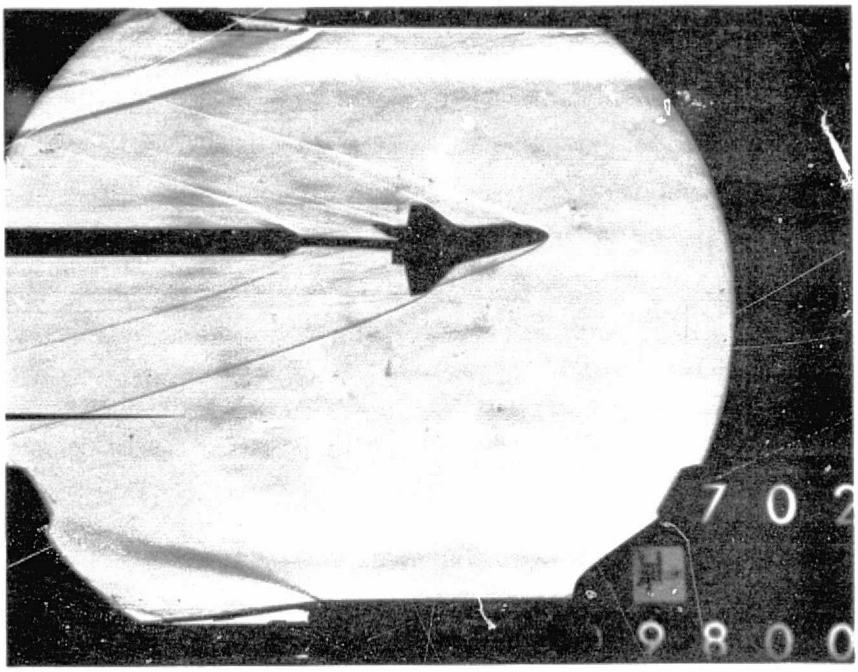


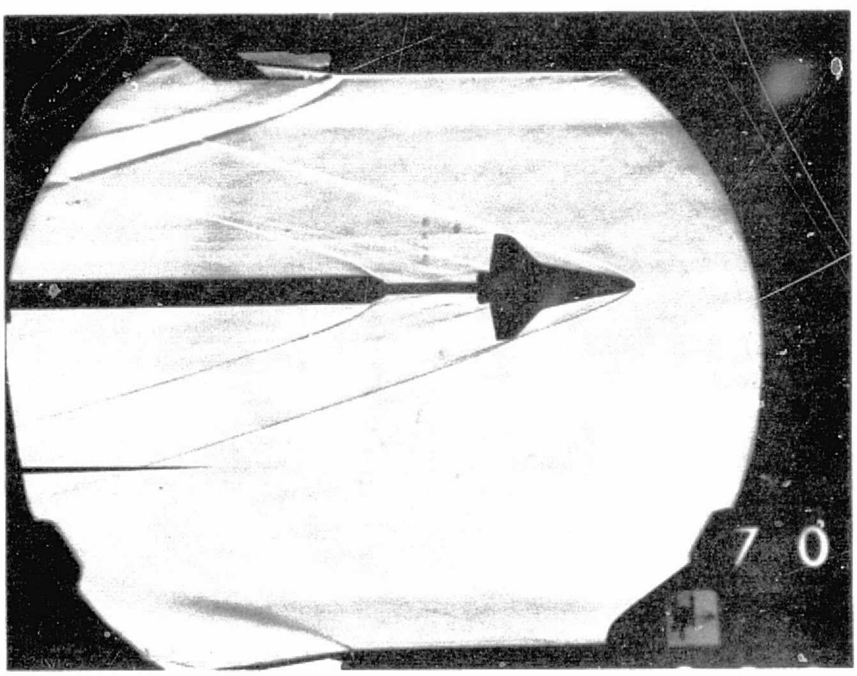


(a) ϕ = 0°

(b) ϕ = 30°

Figure 23.- Schlieren photographs, M = 4.0, α = 10°, h/l = 1.18.

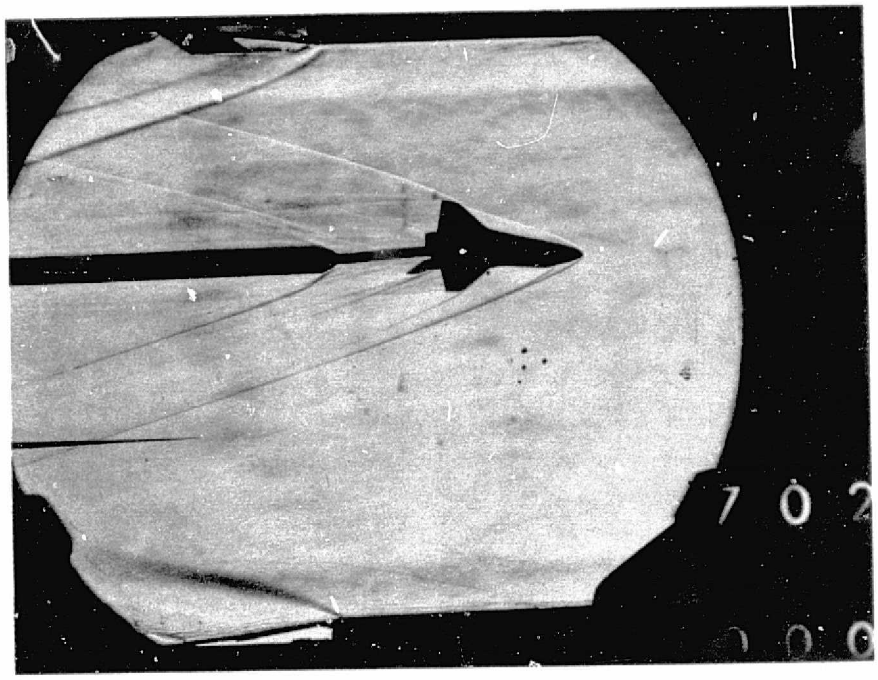




(c) ϕ = 60°

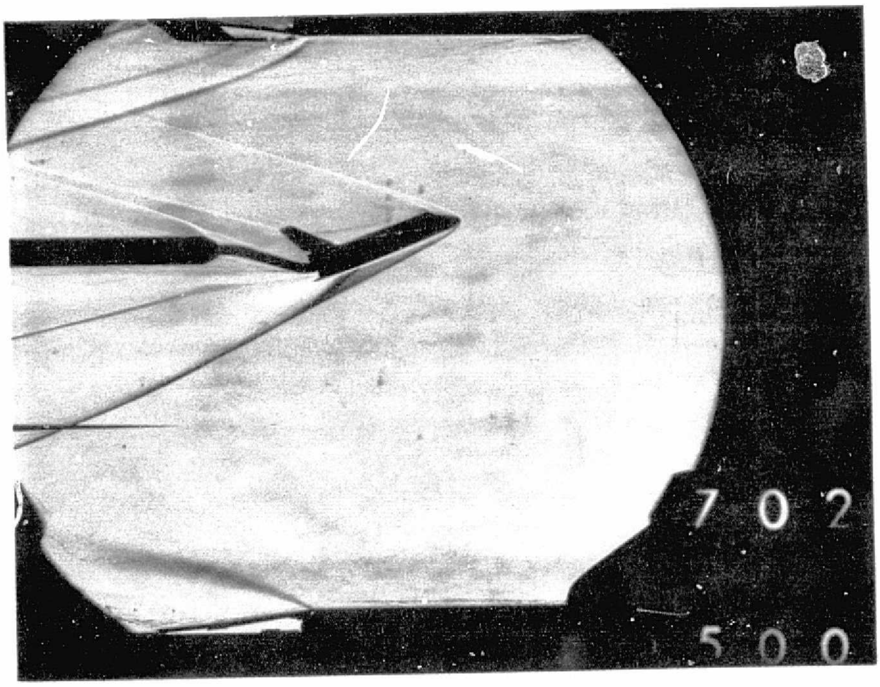
(d) ϕ = 90°

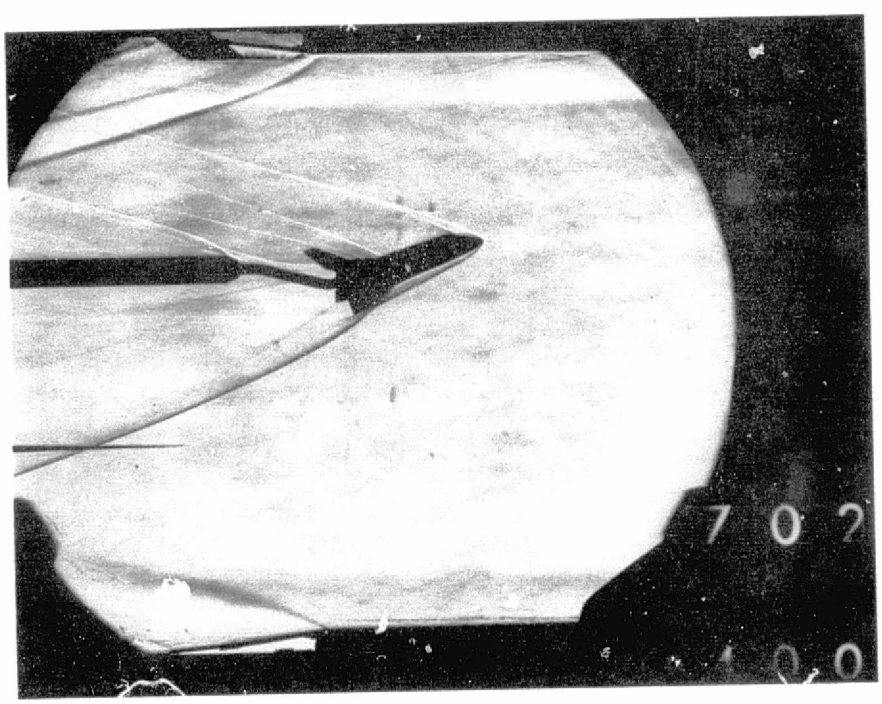
Figure 23.- Continued.



(e) ϕ = 120°

Figure 23.- Concluded.

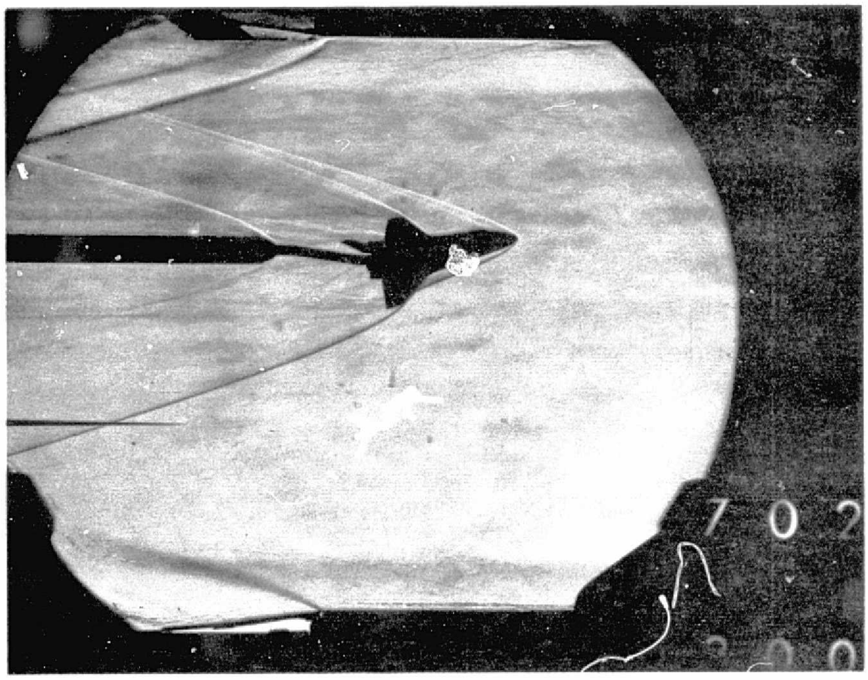


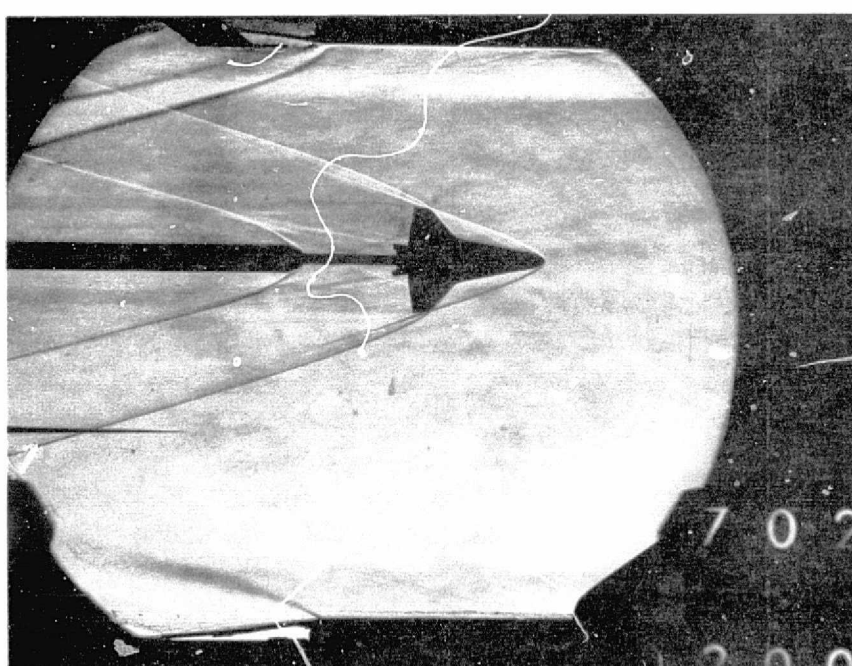


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 24.- Schlieren photographs, $M = 4.0$, $\alpha = 20°$, $h/l = 1.18$.

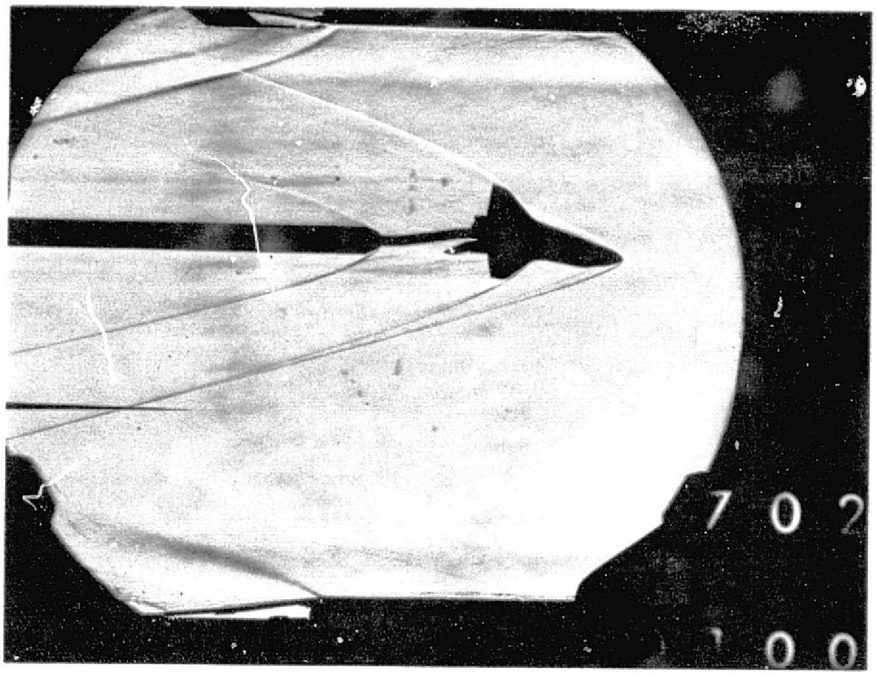




(c) $\phi = 60°$

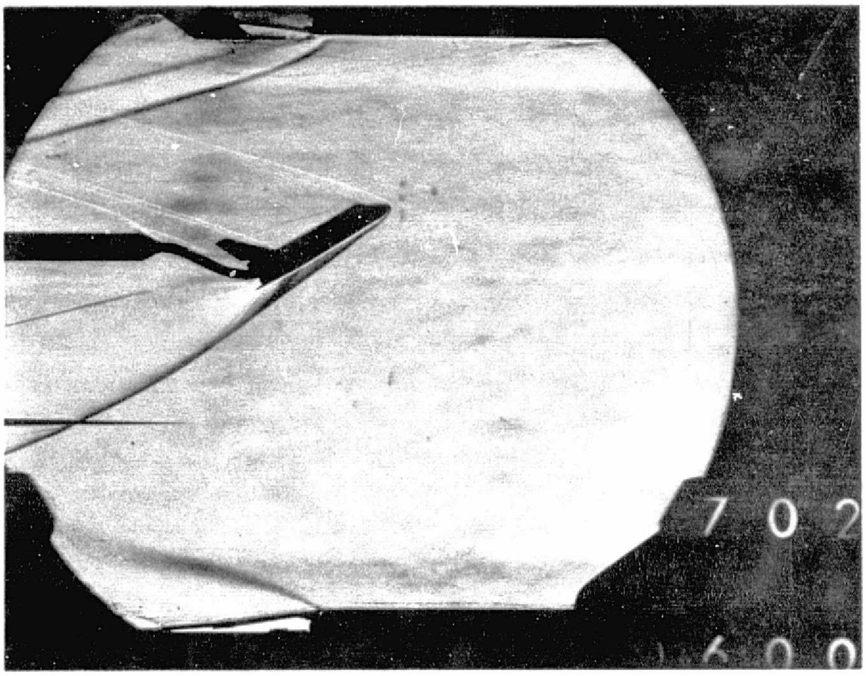
(d) $\phi = 90°$

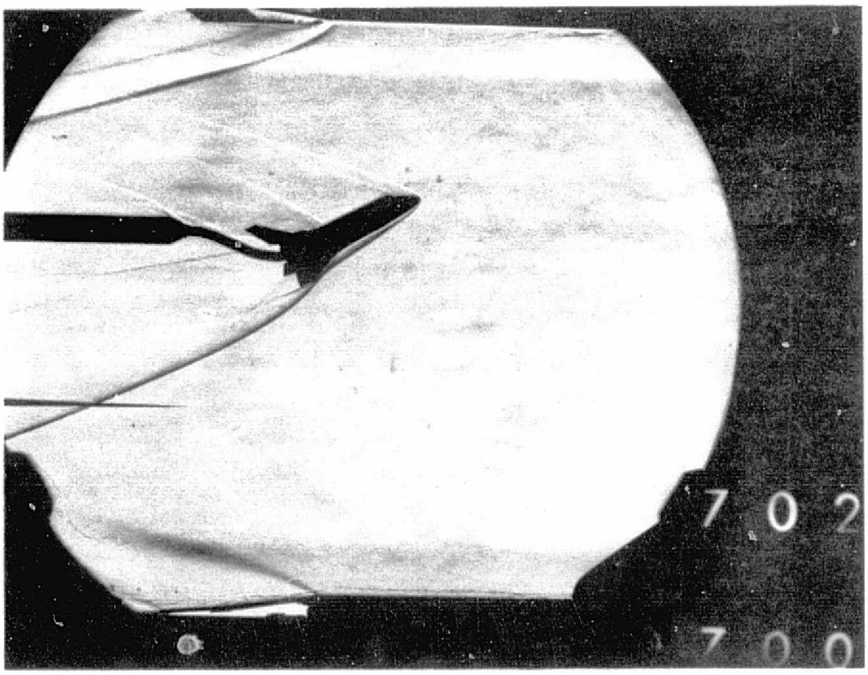
Figure 24.- Continued.



(e) ϕ = 120°

Figure 24.- Concluded.

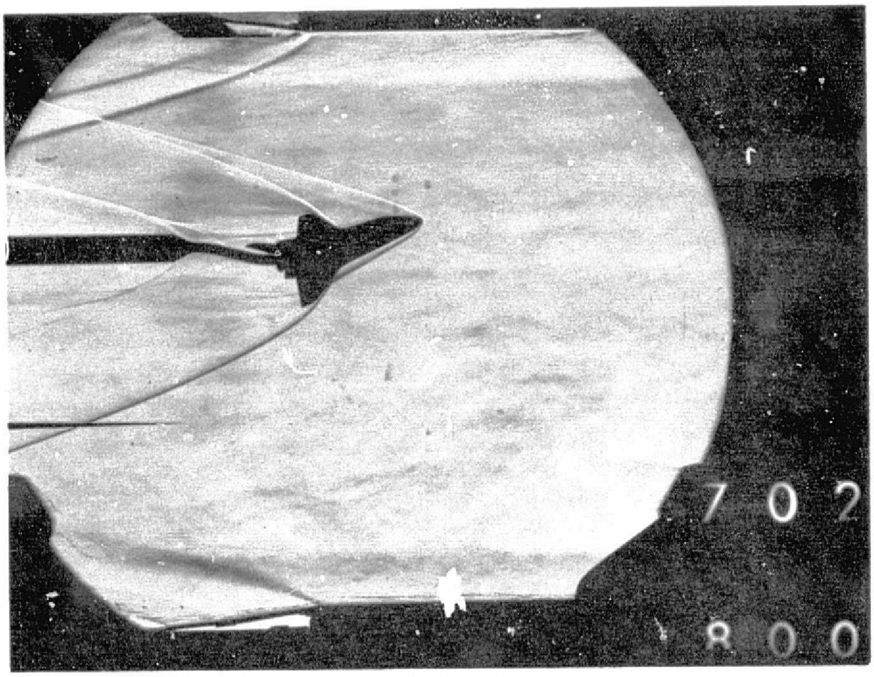


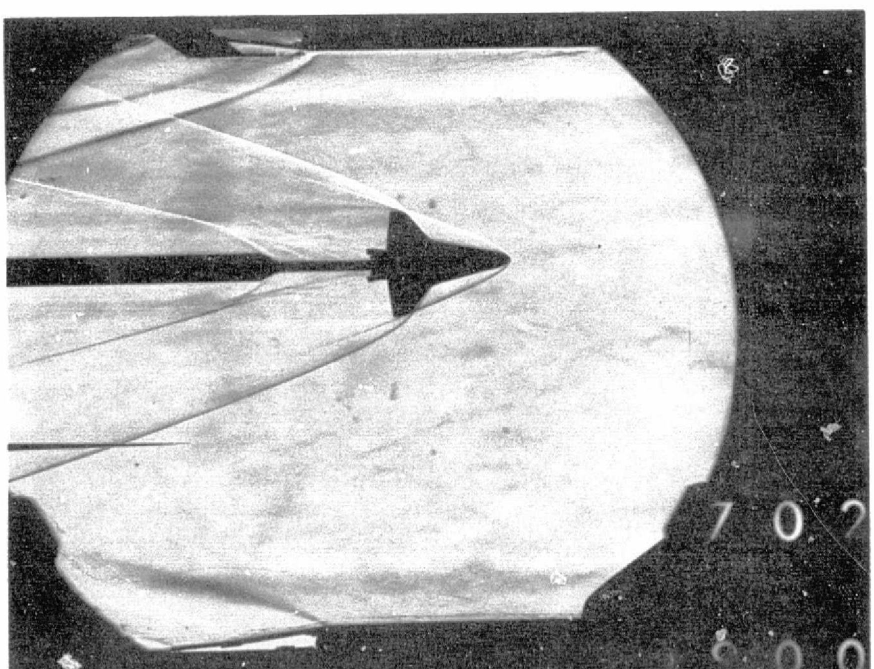


(a) $\phi = 0°$

(b) $\phi = 30°$

Figure 25.- Schlieren photographs, $M = 4.0$, $\alpha = 30°$, $h/l = 1.18$.

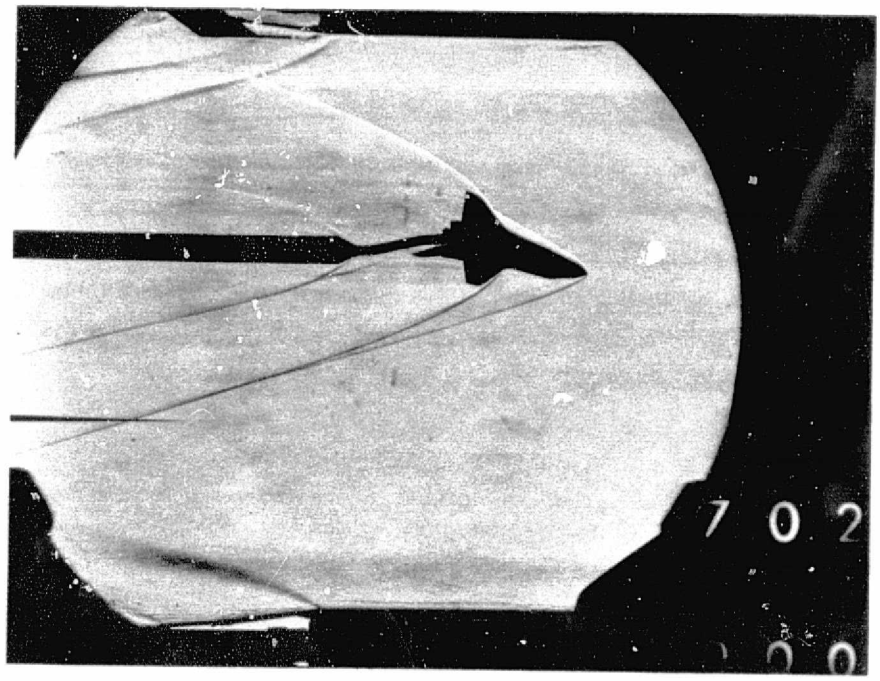




(c) ϕ = 60°

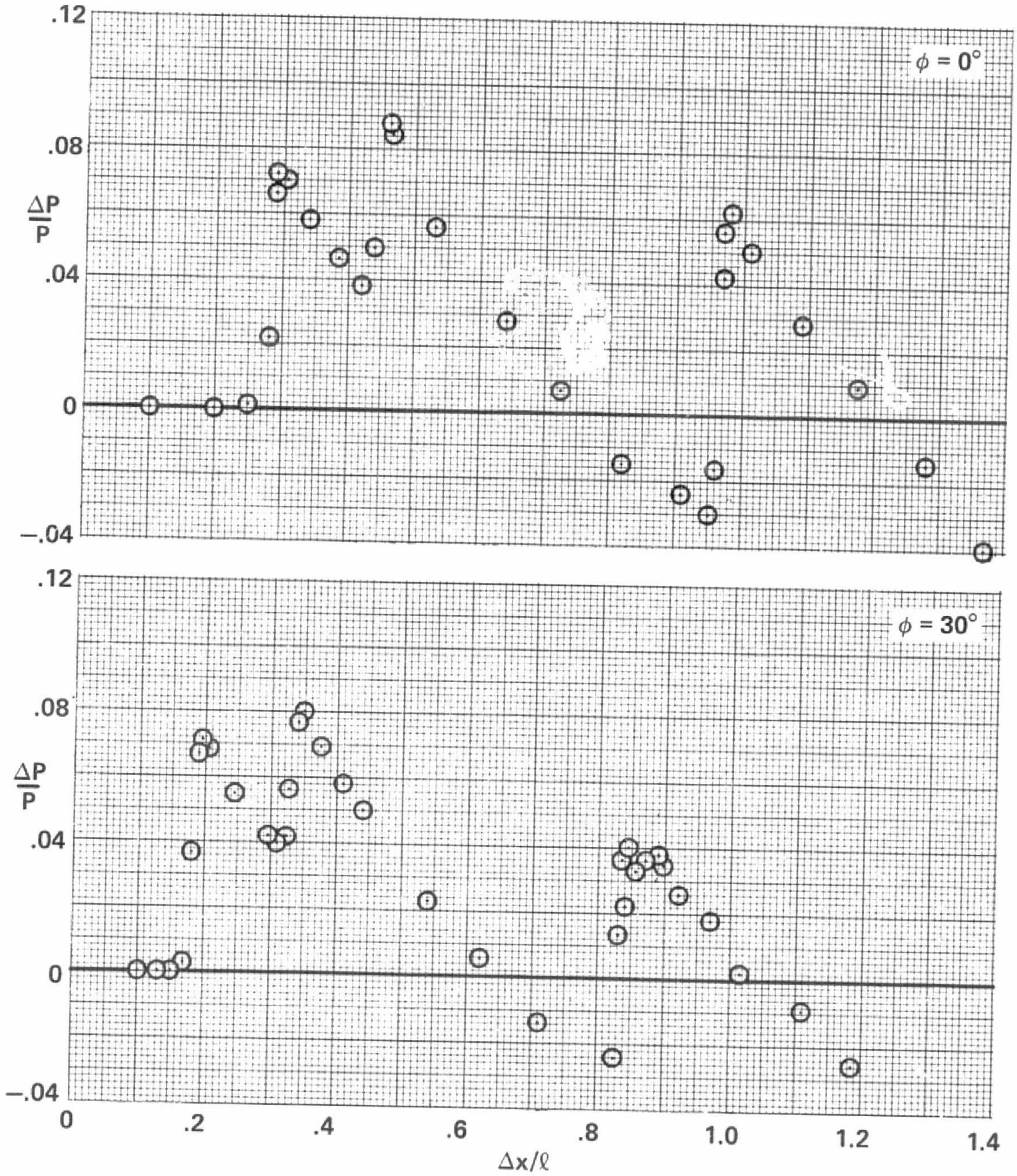
(d) ϕ = 90°

Figure 25.- Continued.



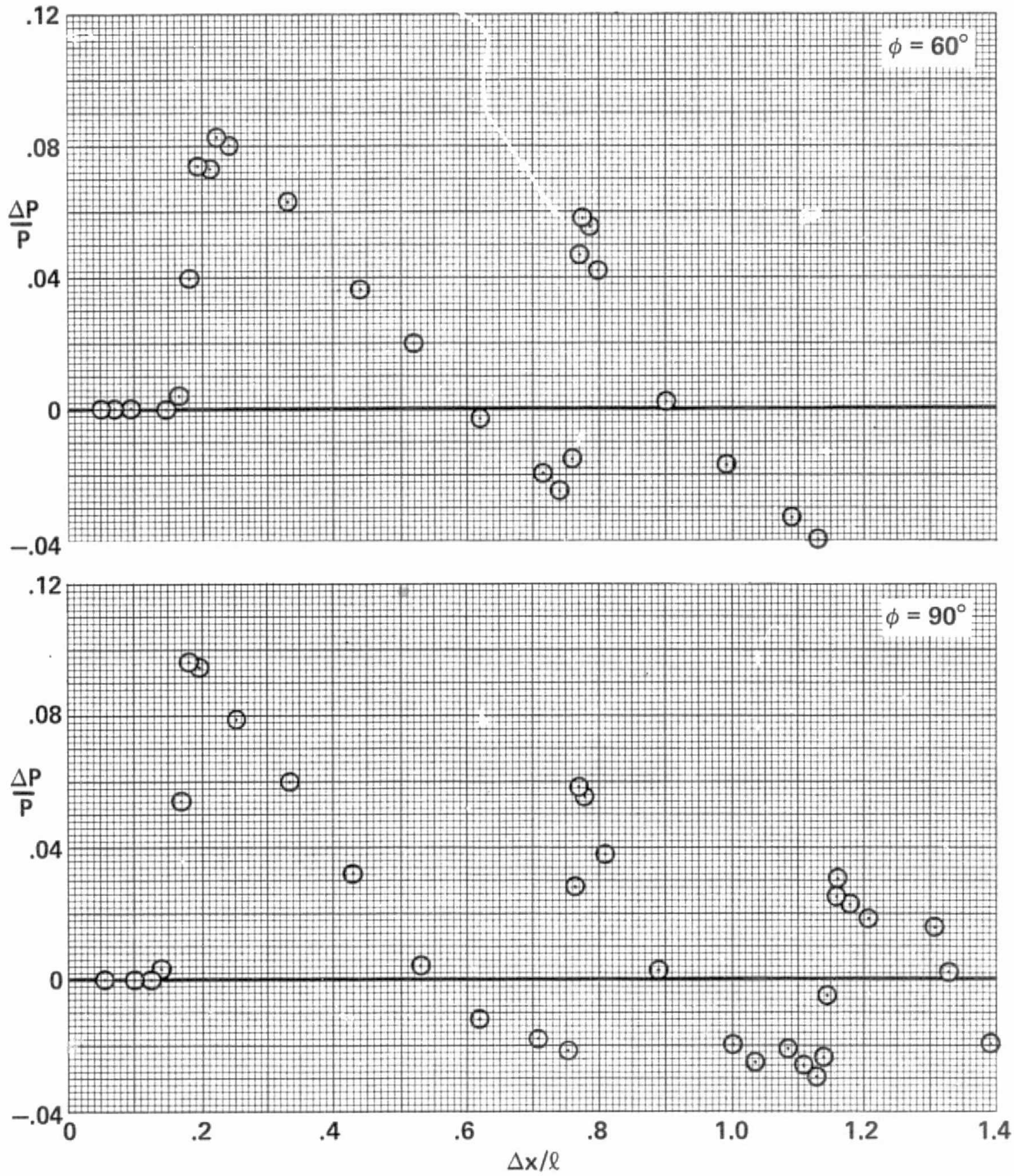
(e) $\phi = 120°$

Figure 25.- Concluded.



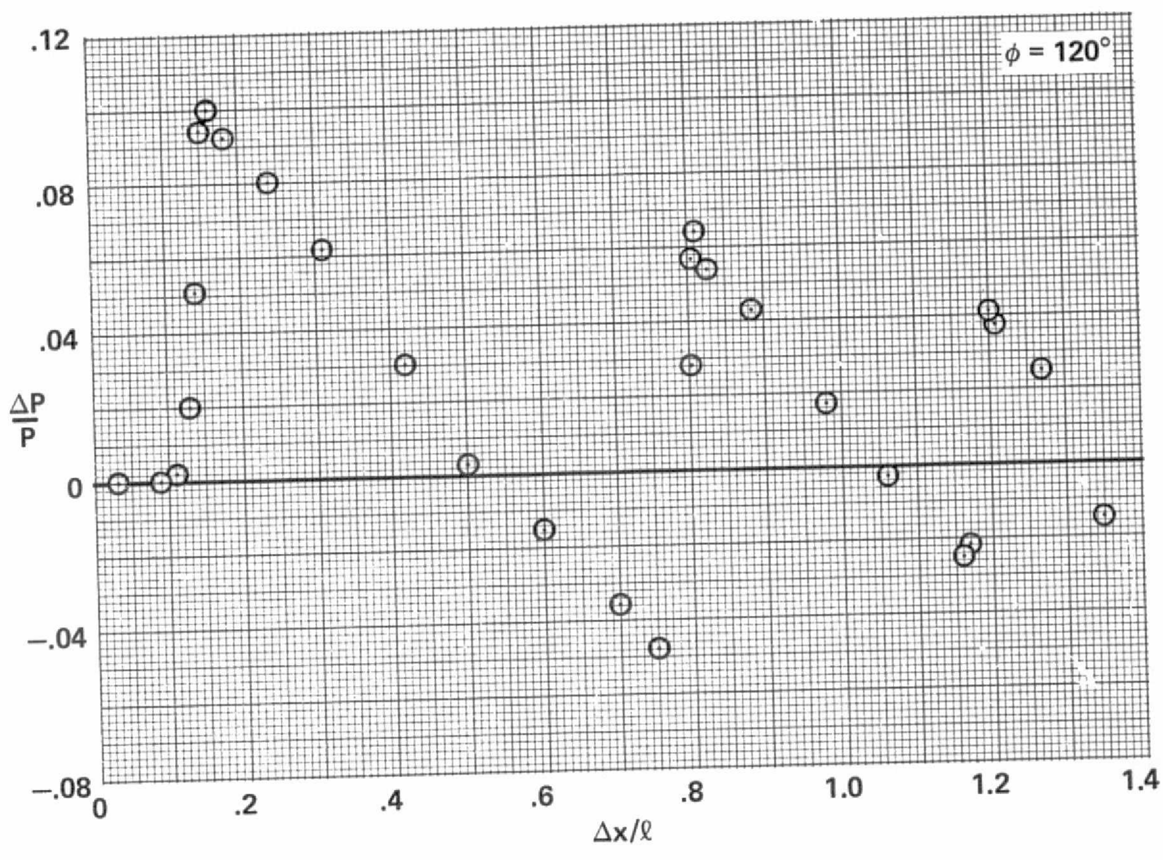
(a) ϕ = 0°, 30°

Figure 26.- Pressure signatures, M = 1.3, α = 0°, h/l = 1.55.



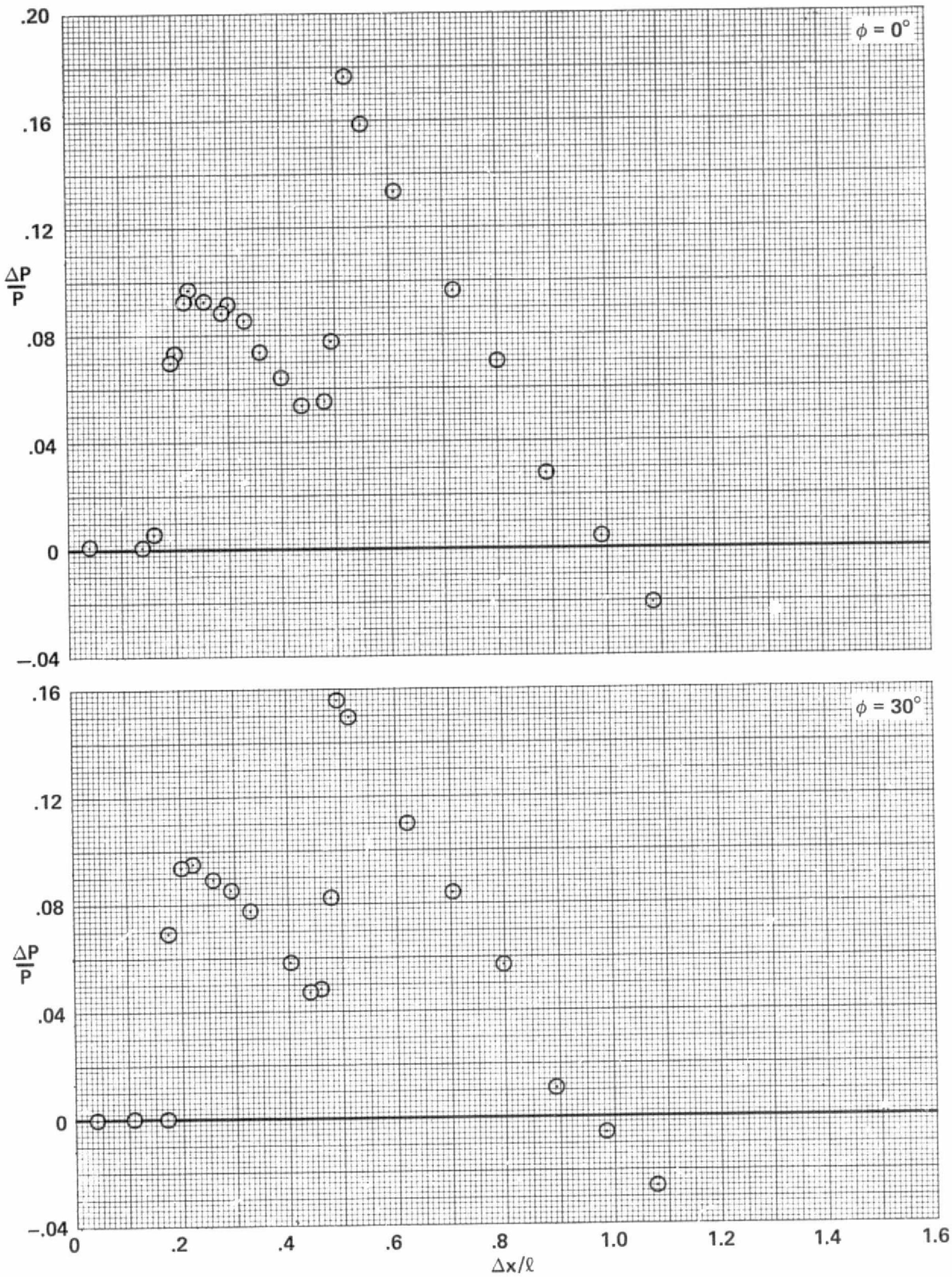
(b) ϕ = 60°, 90°

Figure 26.- Continued.



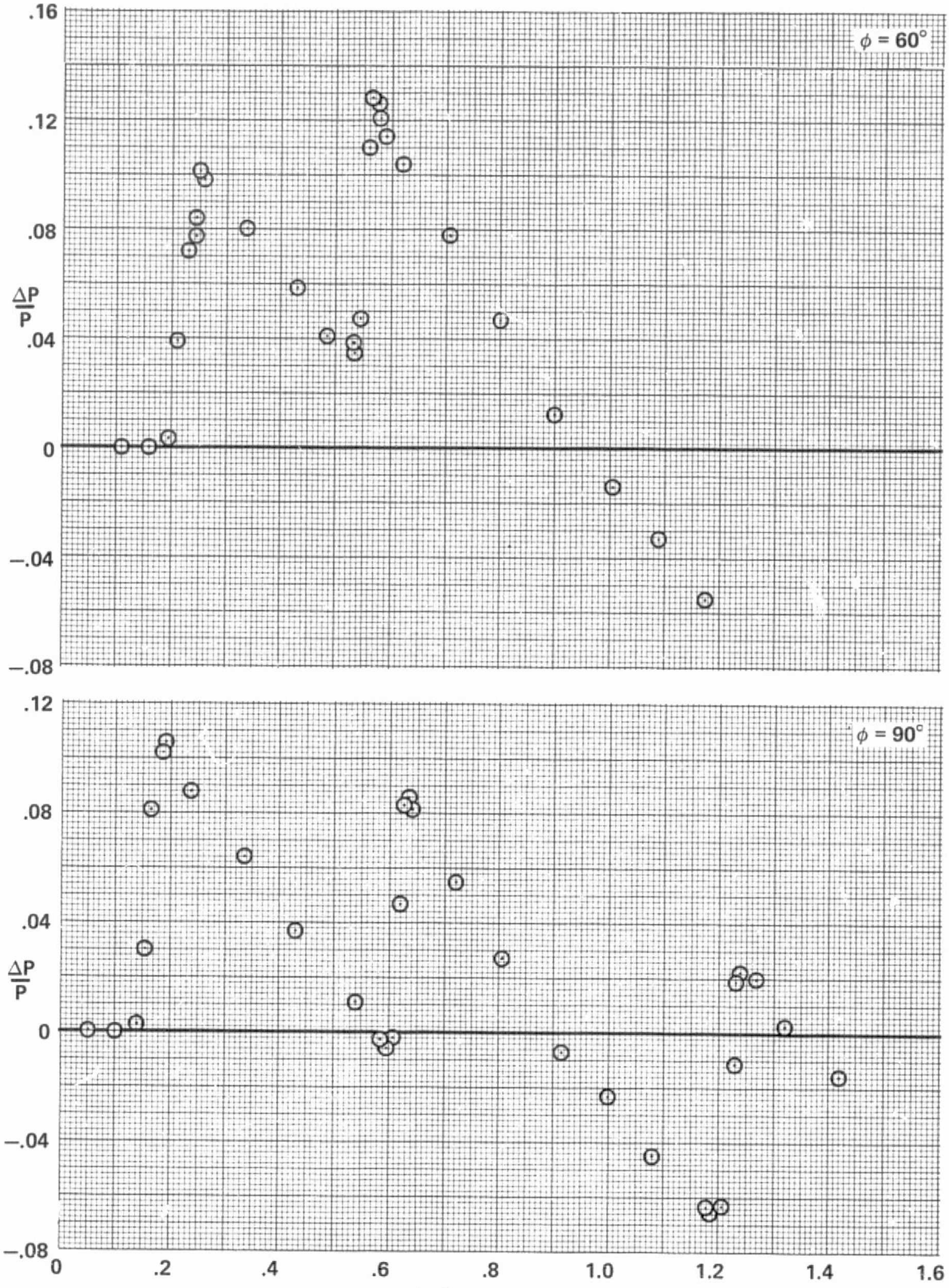
(c) ϕ = 120°

Figure 26.- Concluded.



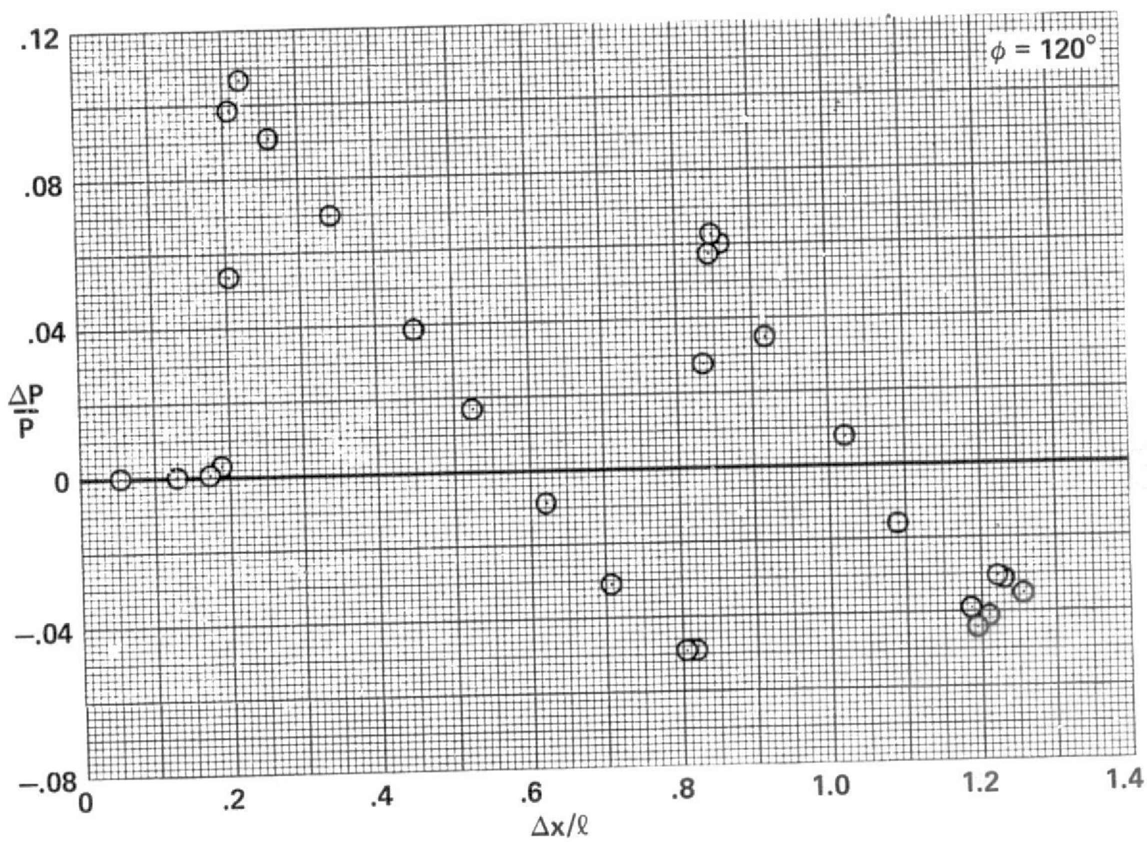
(a) $\phi = 0°, 30°$

Figure 27.- Pressure signatures, $M = 1.3$, $\alpha = 10°$, $h/l = 1.55$.



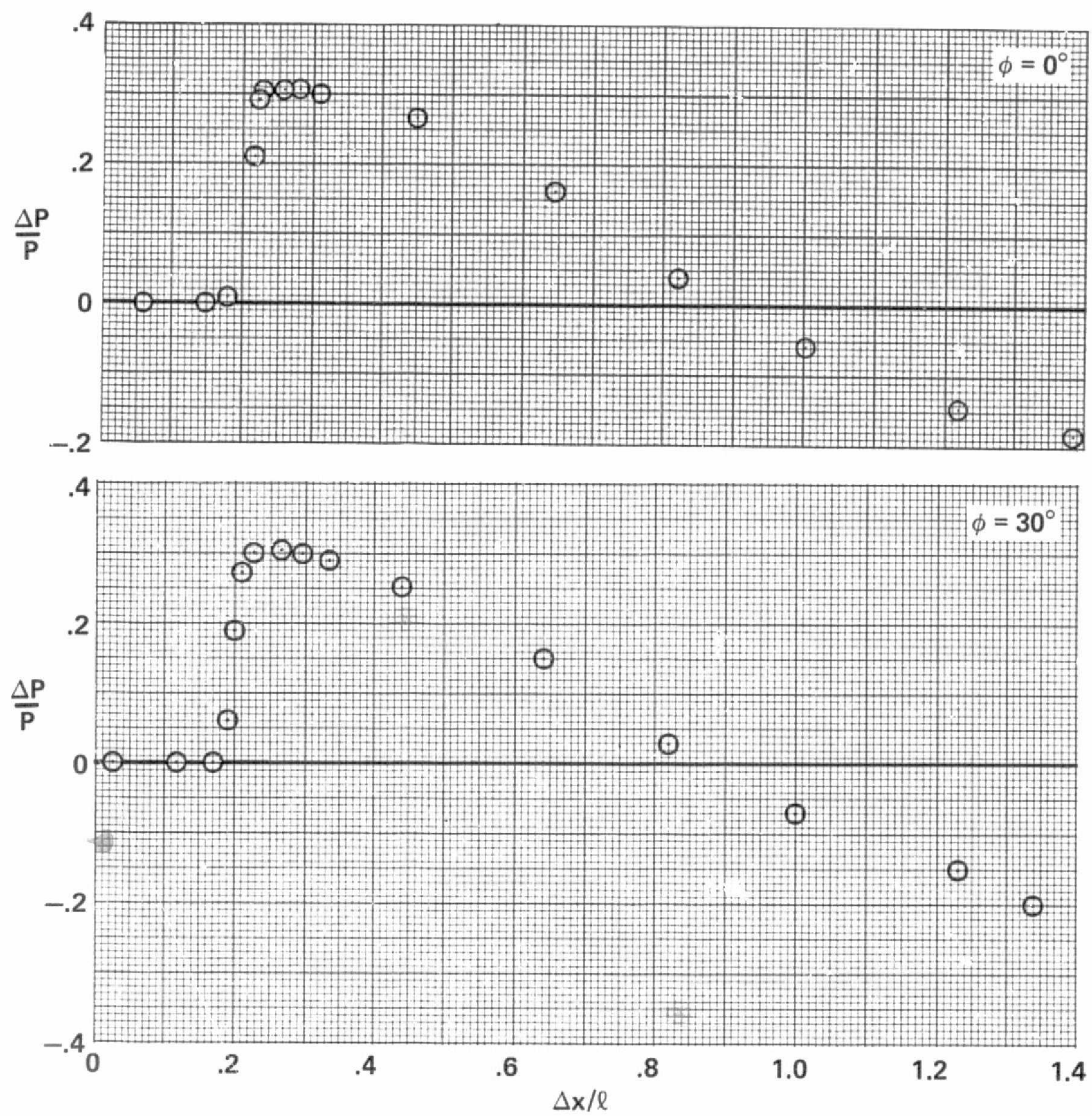
(b) ϕ = 60°, 90°

Figure 27.- Continued.



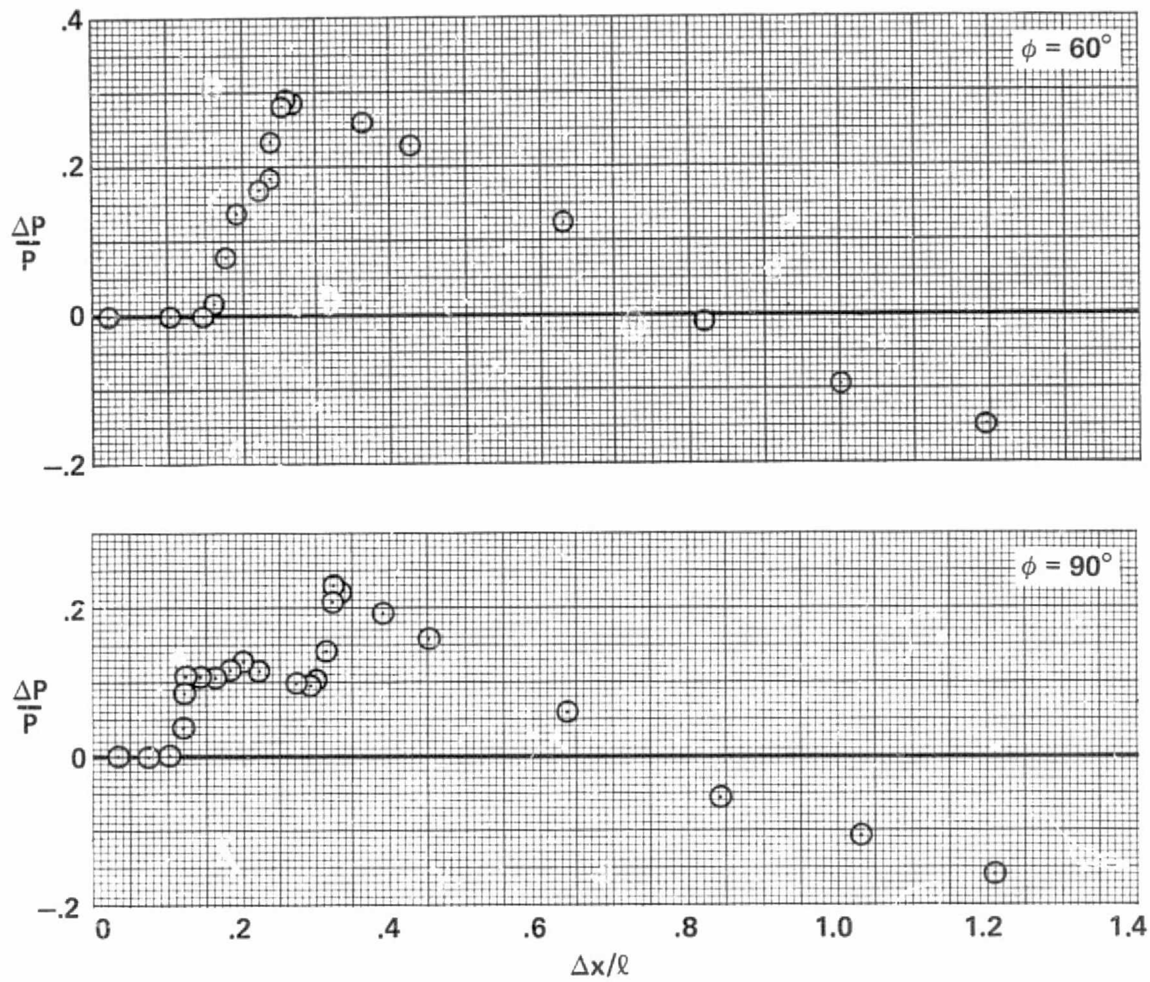
(c) ϕ = 120°

Figure 27.- Concluded.



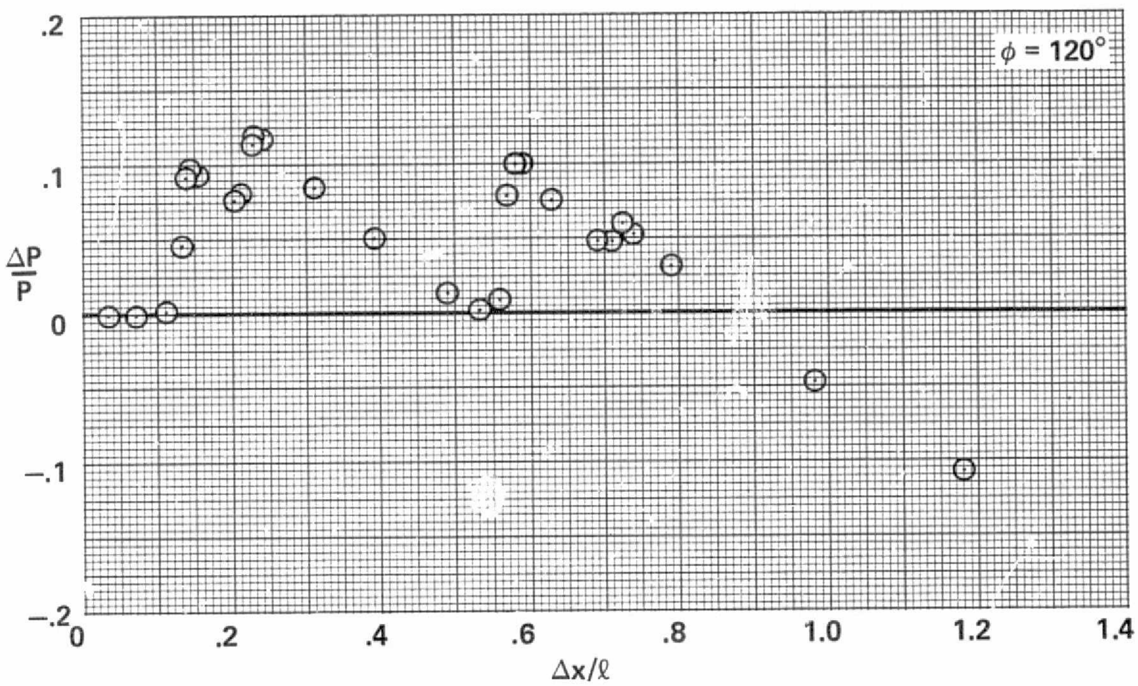
(a) ϕ = 0°, 30°

Figure 28.- Pressure signatures, M = 1.3, α = 20°, h/l = 1.18.



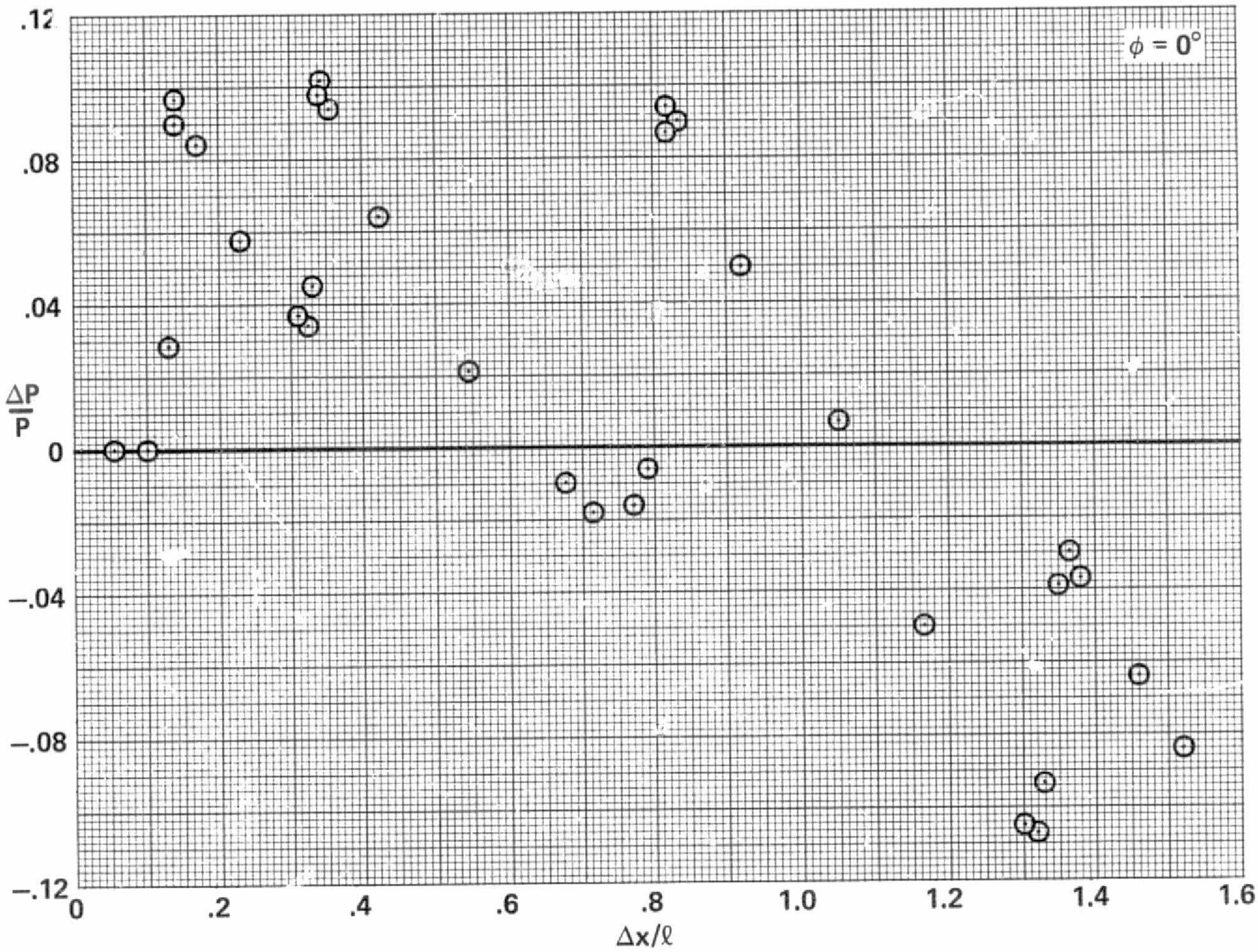
(b) ϕ = 60°, 90°

Figure 28.- Continued.



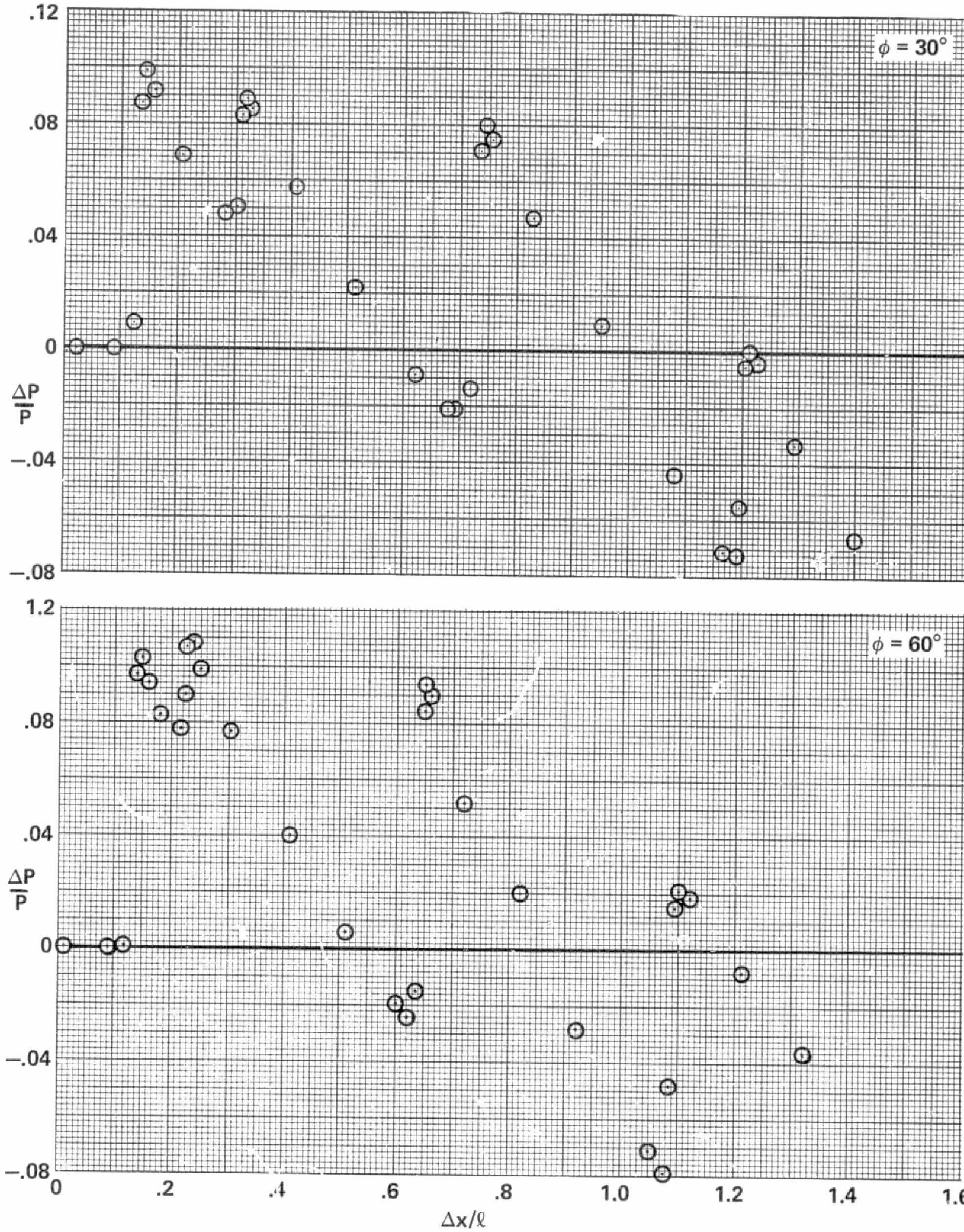
(c) ϕ = 120°

Figure 28.- Concluded.



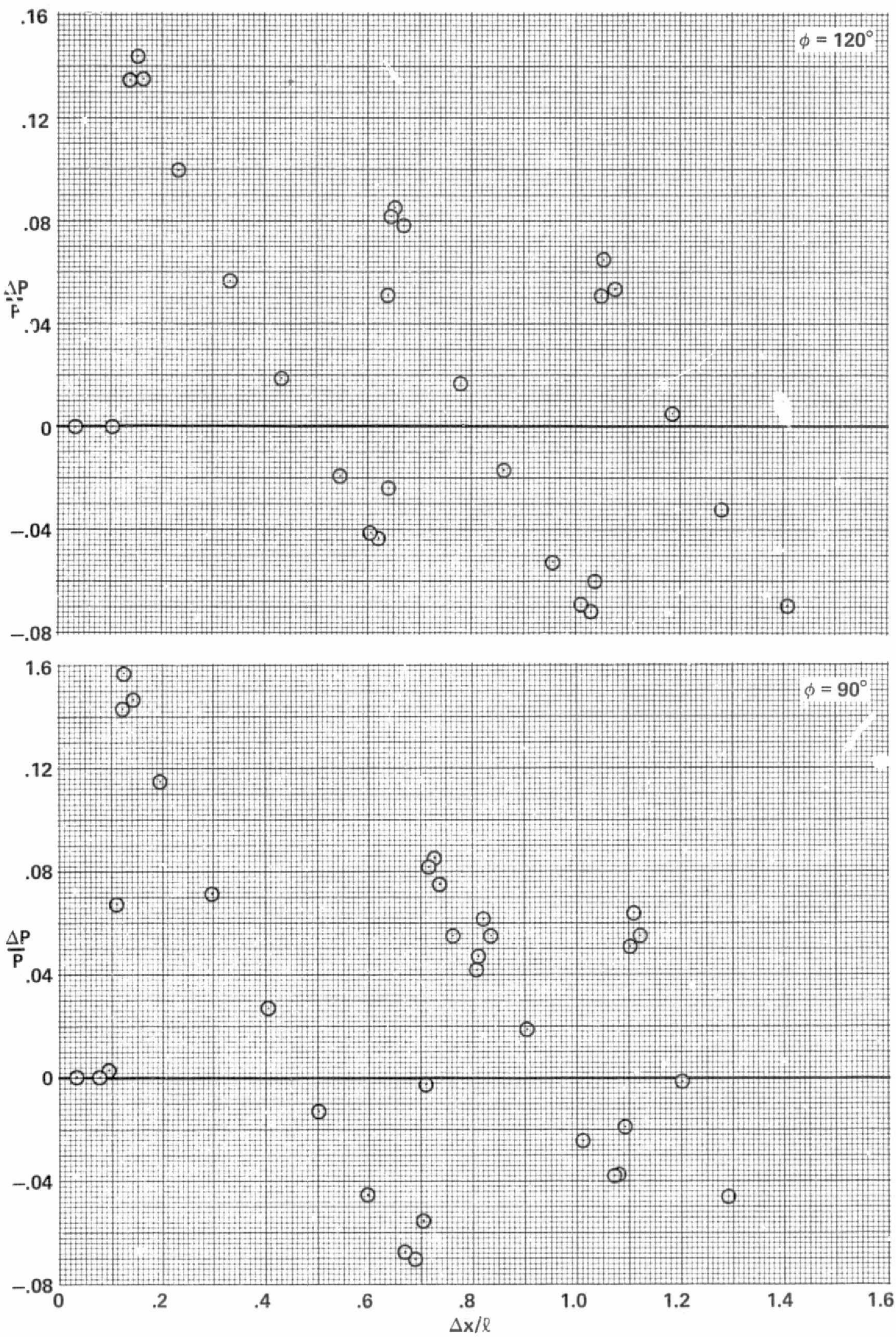
(a) $\phi = 0°$

Figure 29.- Pressure signatures, $M = 1.5$, $\alpha = 0°$, $h/l = 1.18$.



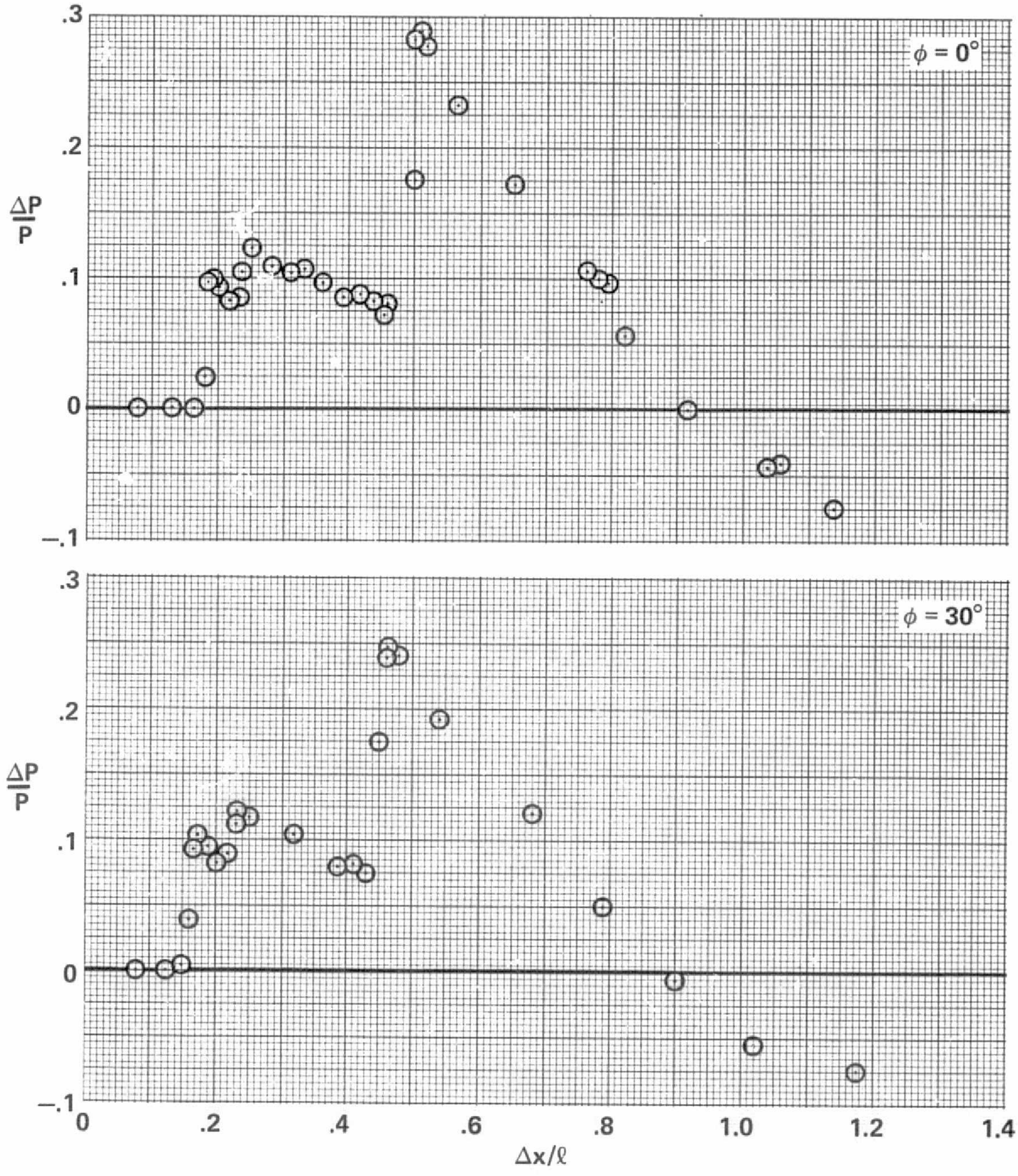
(b) ϕ = 30°, 60°

Figure 29.- Continued.



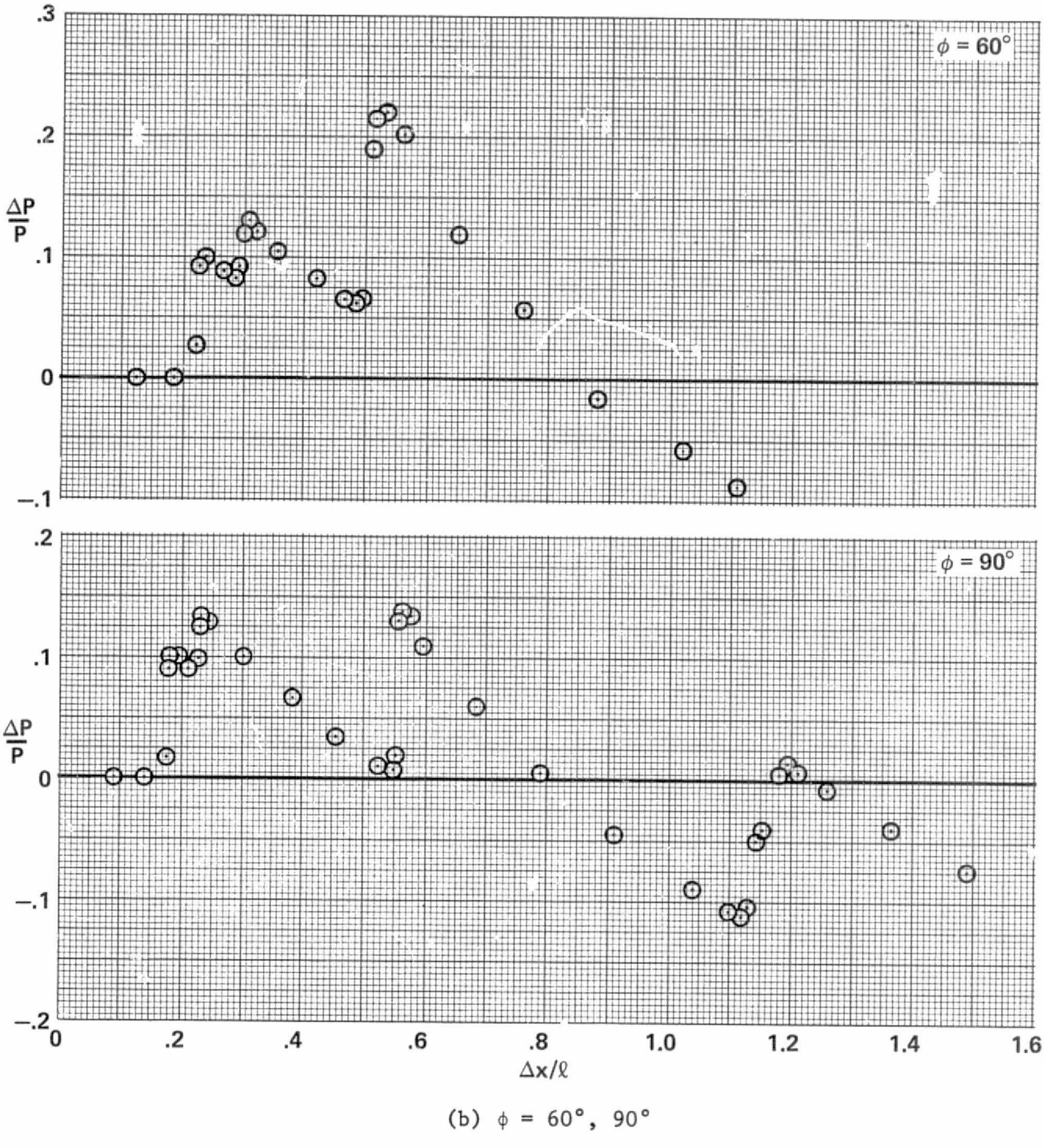
(c) ϕ = 90°, 120°

Figure 29.- Concluded.



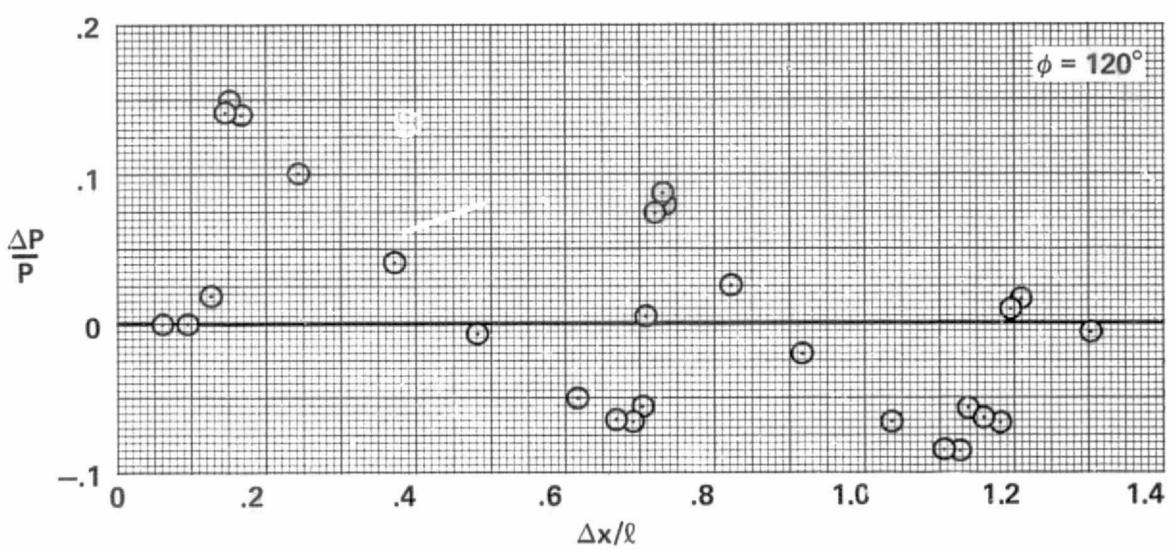
(a) ϕ = 0°, 30°

Figure 30.- Pressure signatures, M = 1.5, α = 10°, h/l = 1.18.



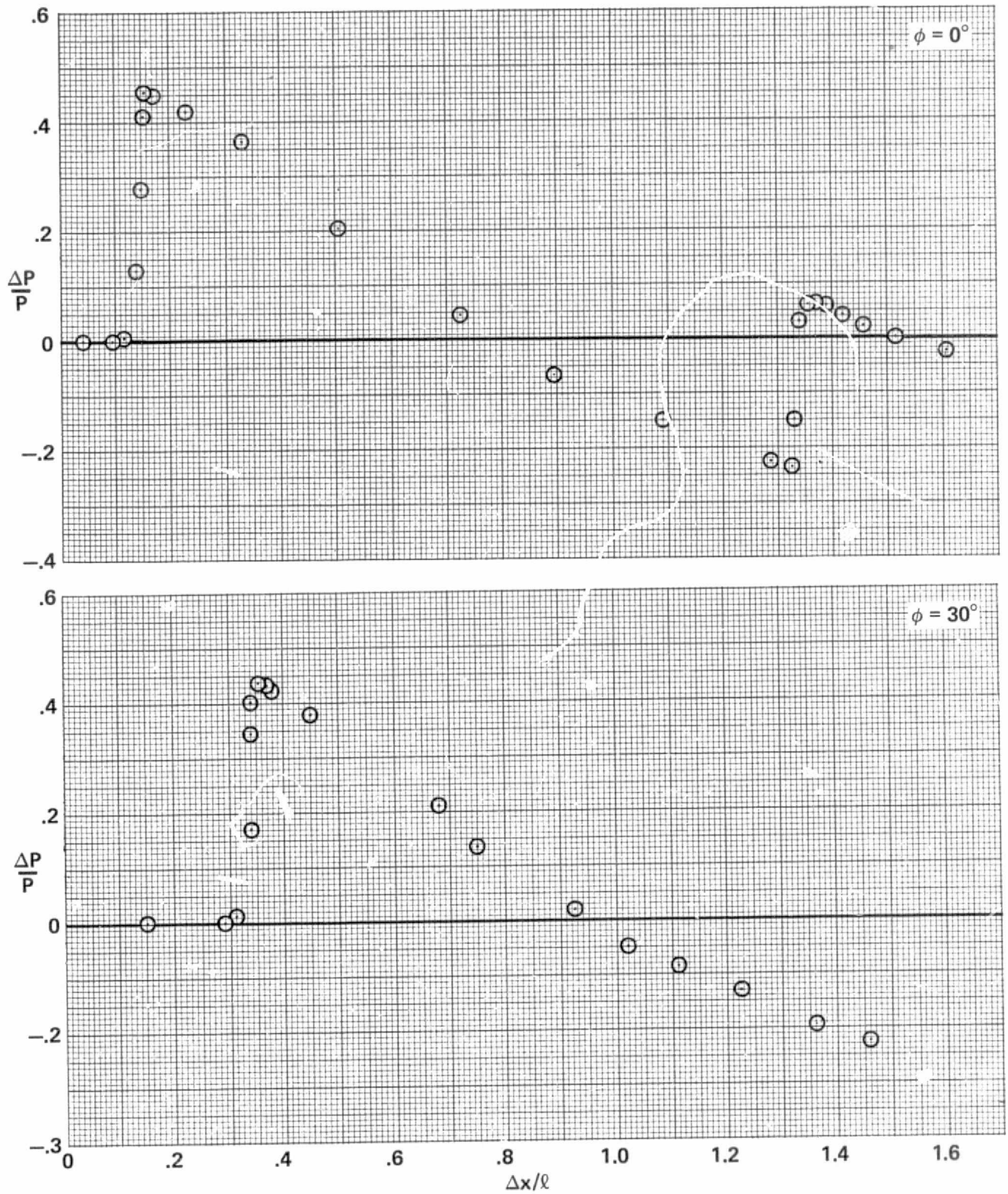
(b) ϕ = 60°, 90°

Figure 30.- Continued.



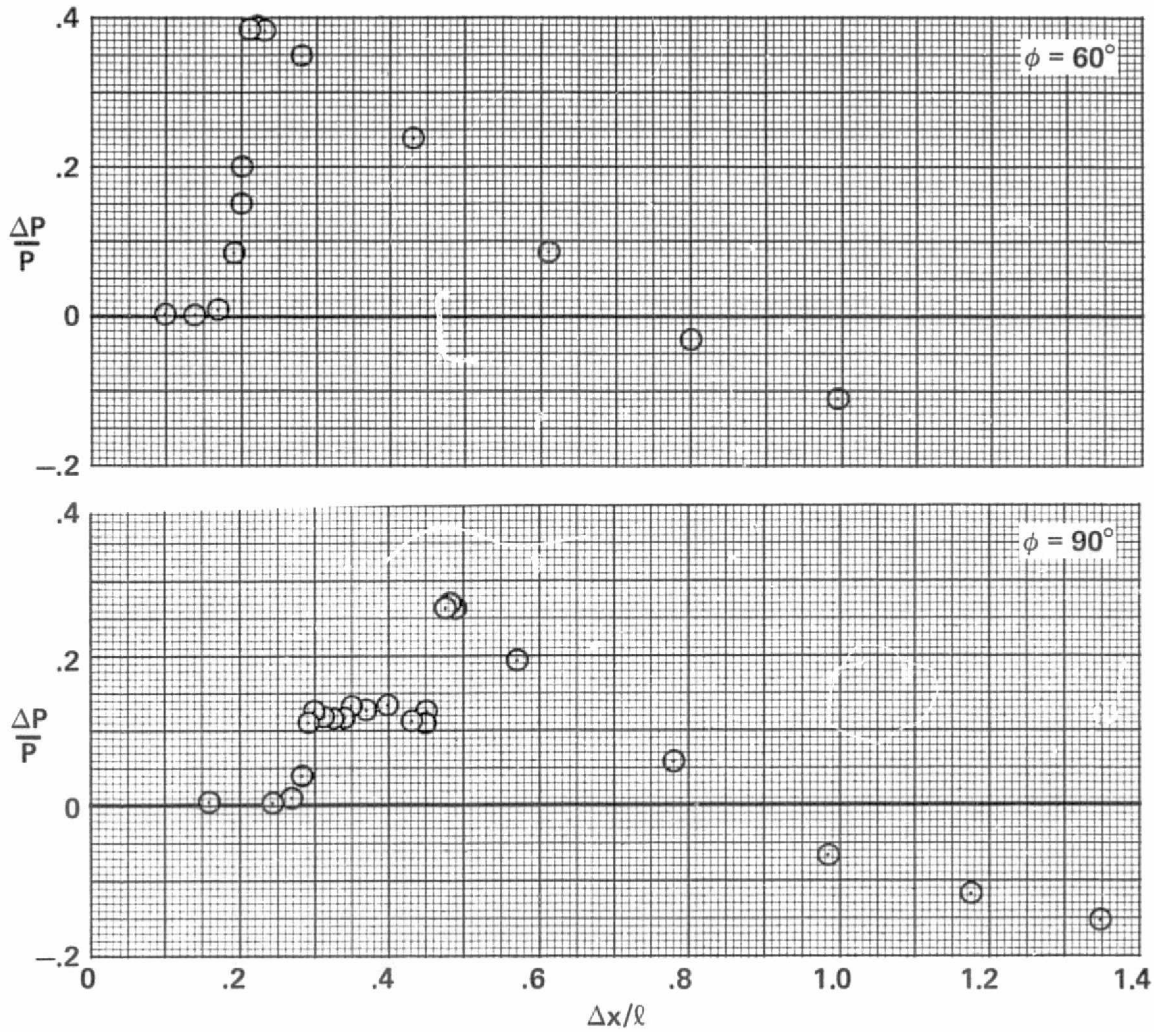
(c) ϕ = 120°

Figure 30.- Concluded.



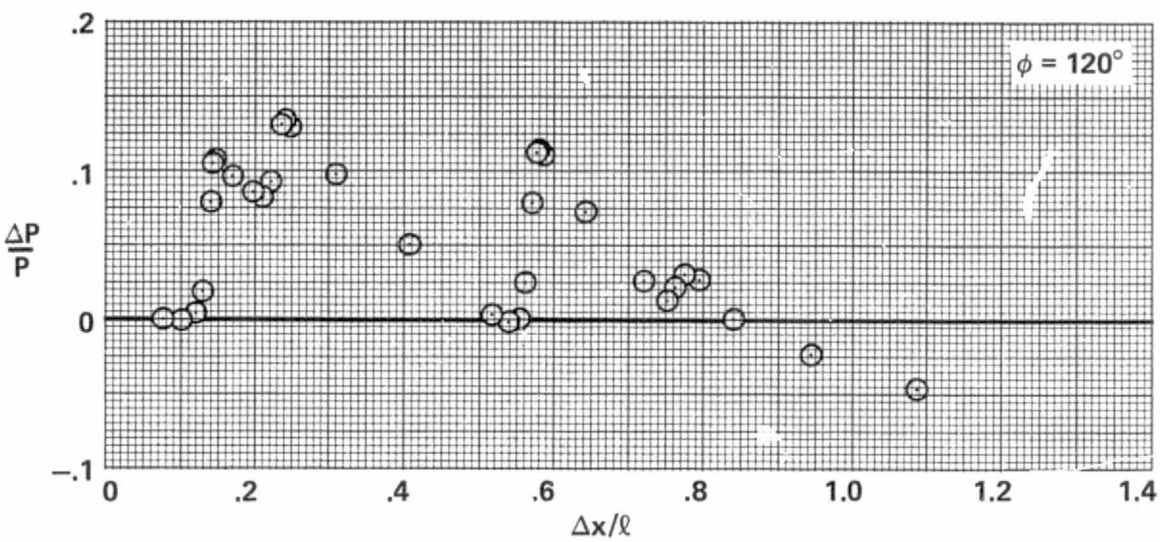
(a) ϕ = 0°, 30°

Figure 31.- Pressure signatures, $M = 1.5$, $\alpha = 20°$, $h/l = 1.18$.



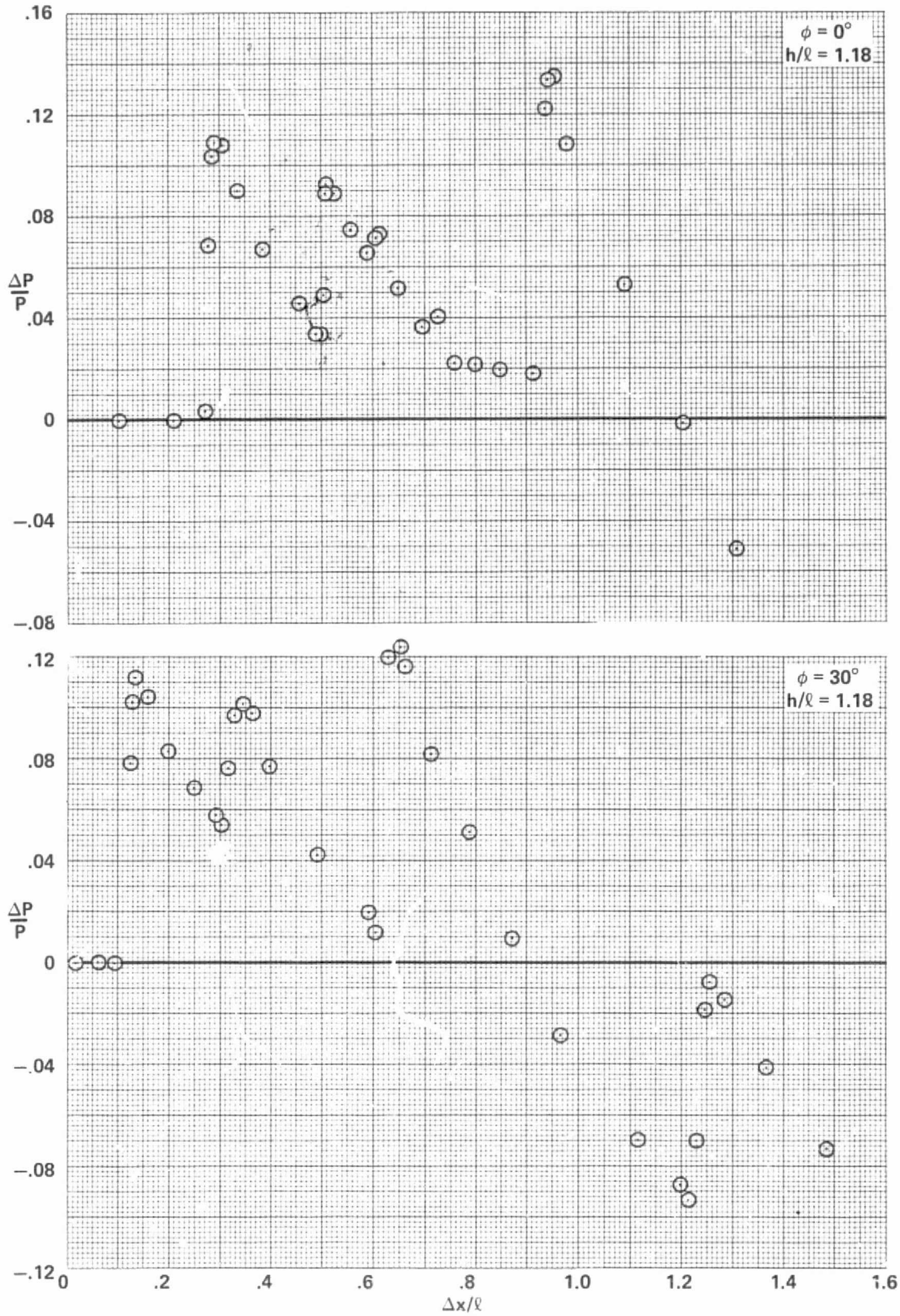
(b) ϕ = 60°, 90°

Figure 31.- Continued



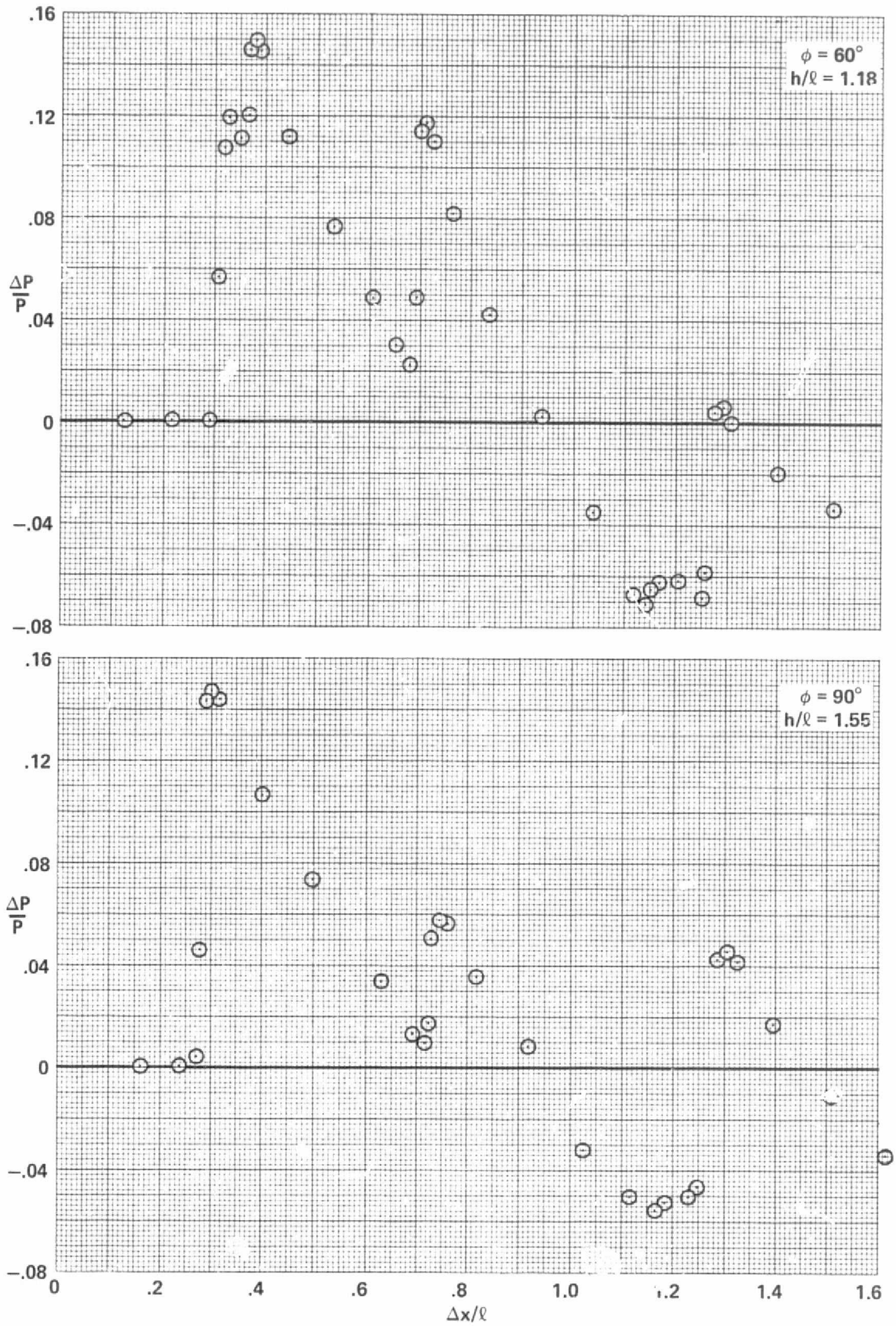
(c) ϕ = 120°

Figure 31.- Concluded.



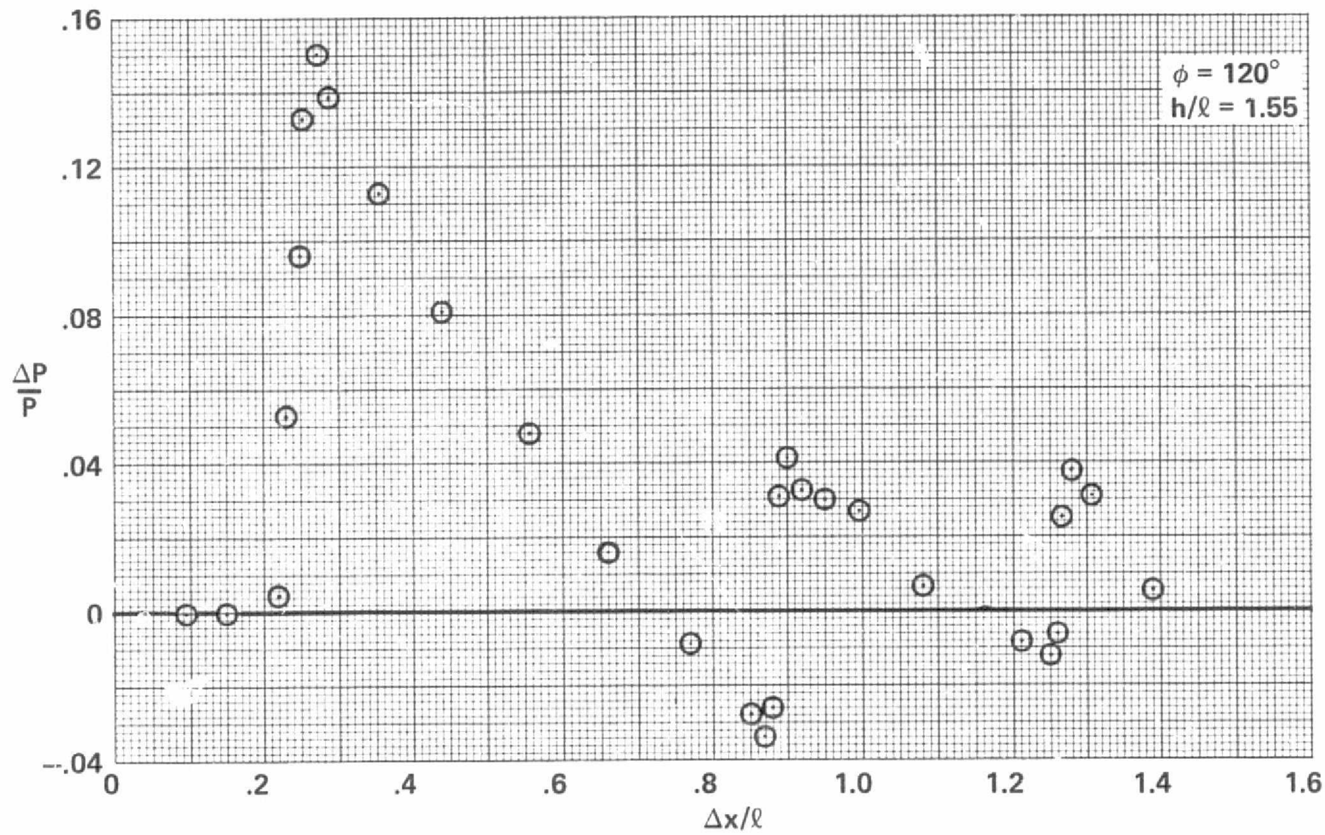
(a) ϕ = 0°, 30°

Figure 32.- Pressure signatures, M = 2.0, α = 0°.



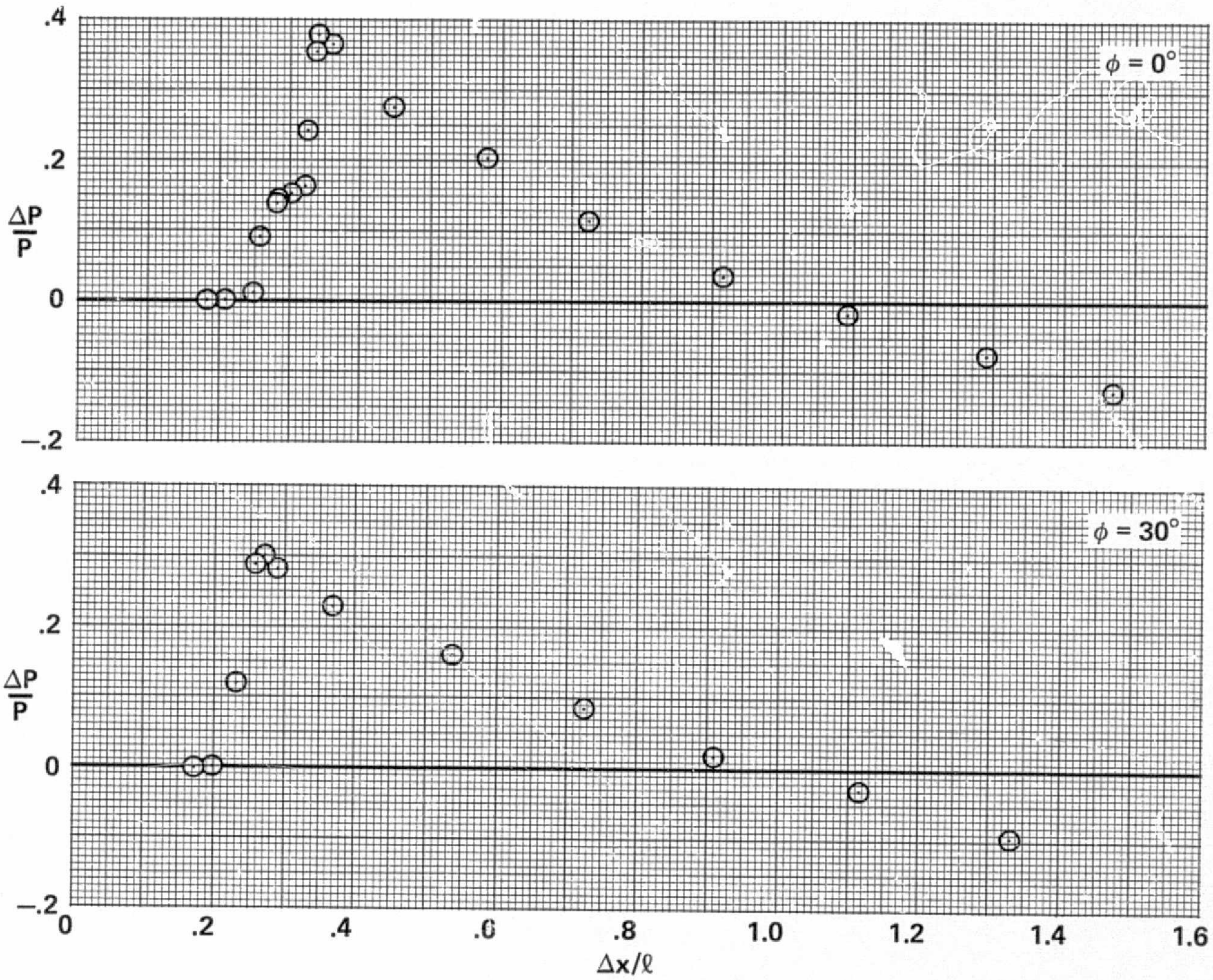
(b) ϕ = 60°, 90°

Figure 32.- Continued.



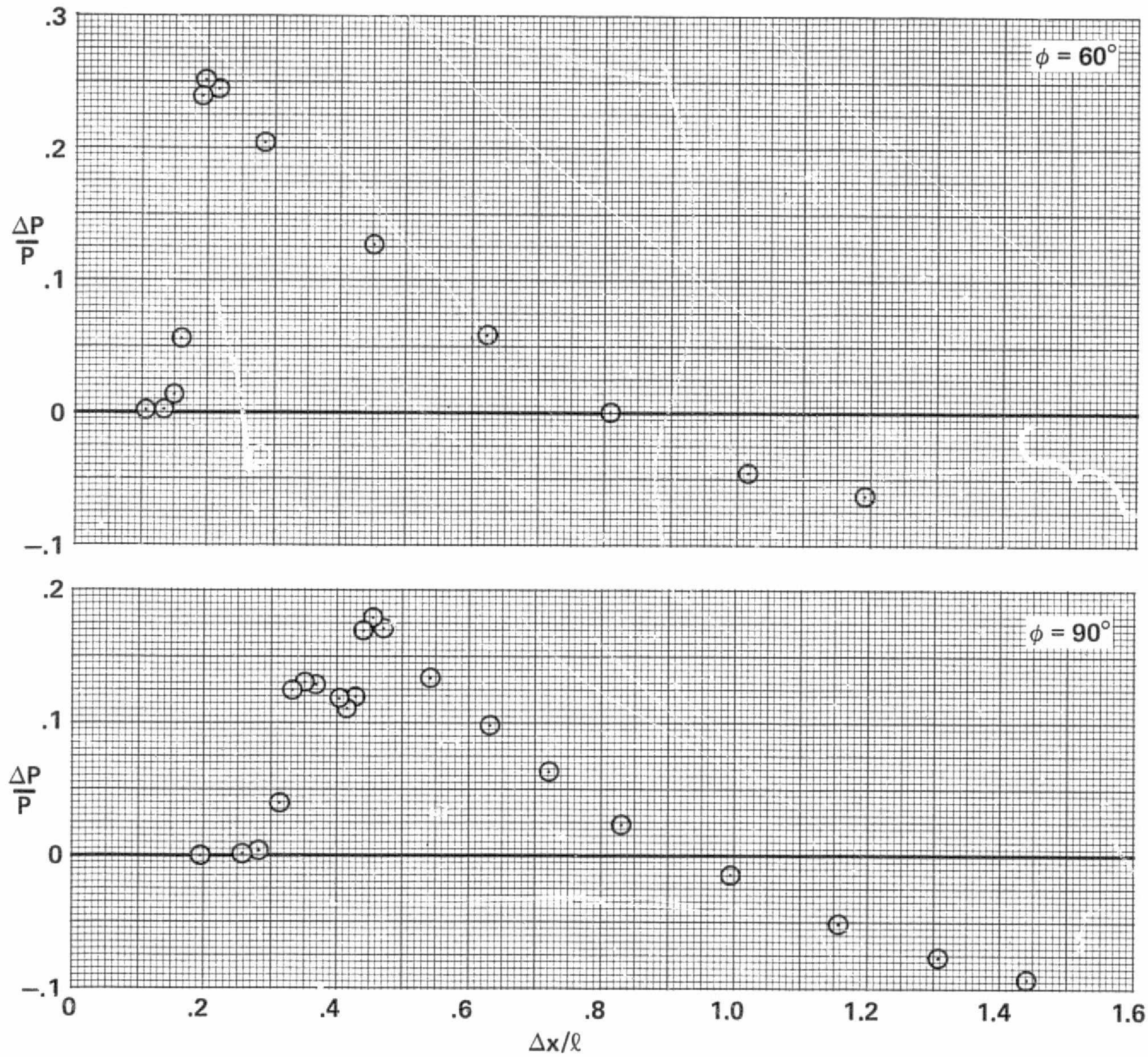
(c) ϕ = 120°

Figure 32.- Concluded.



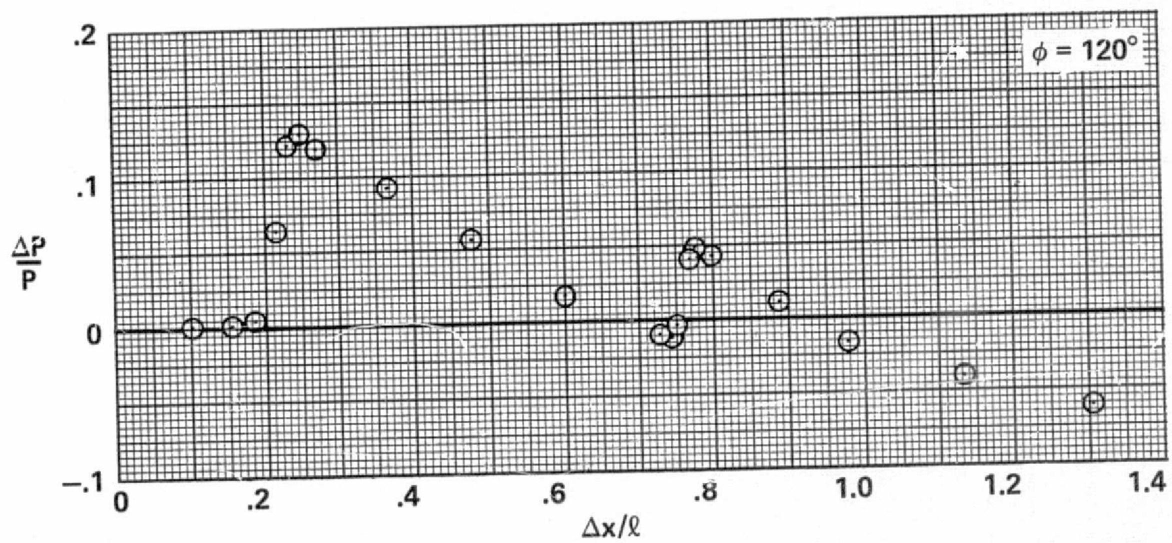
(a) ϕ = 0°, 30°

Figure 33.- Pressure signatures, M = 2.0, α = 10°, h/l = 1.55.



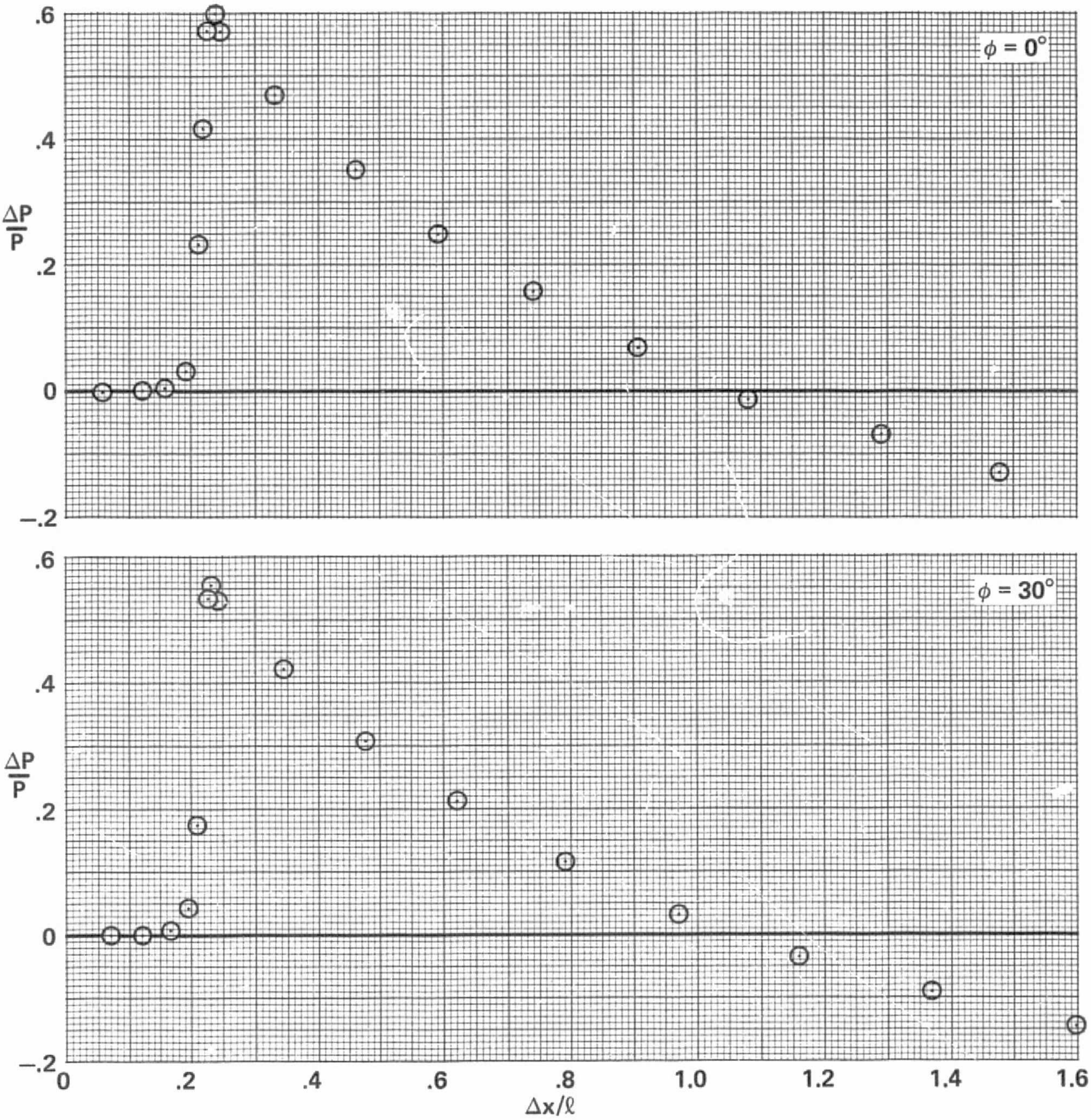
(b) ϕ = 60°, 90°

Figure 33.- Continued.



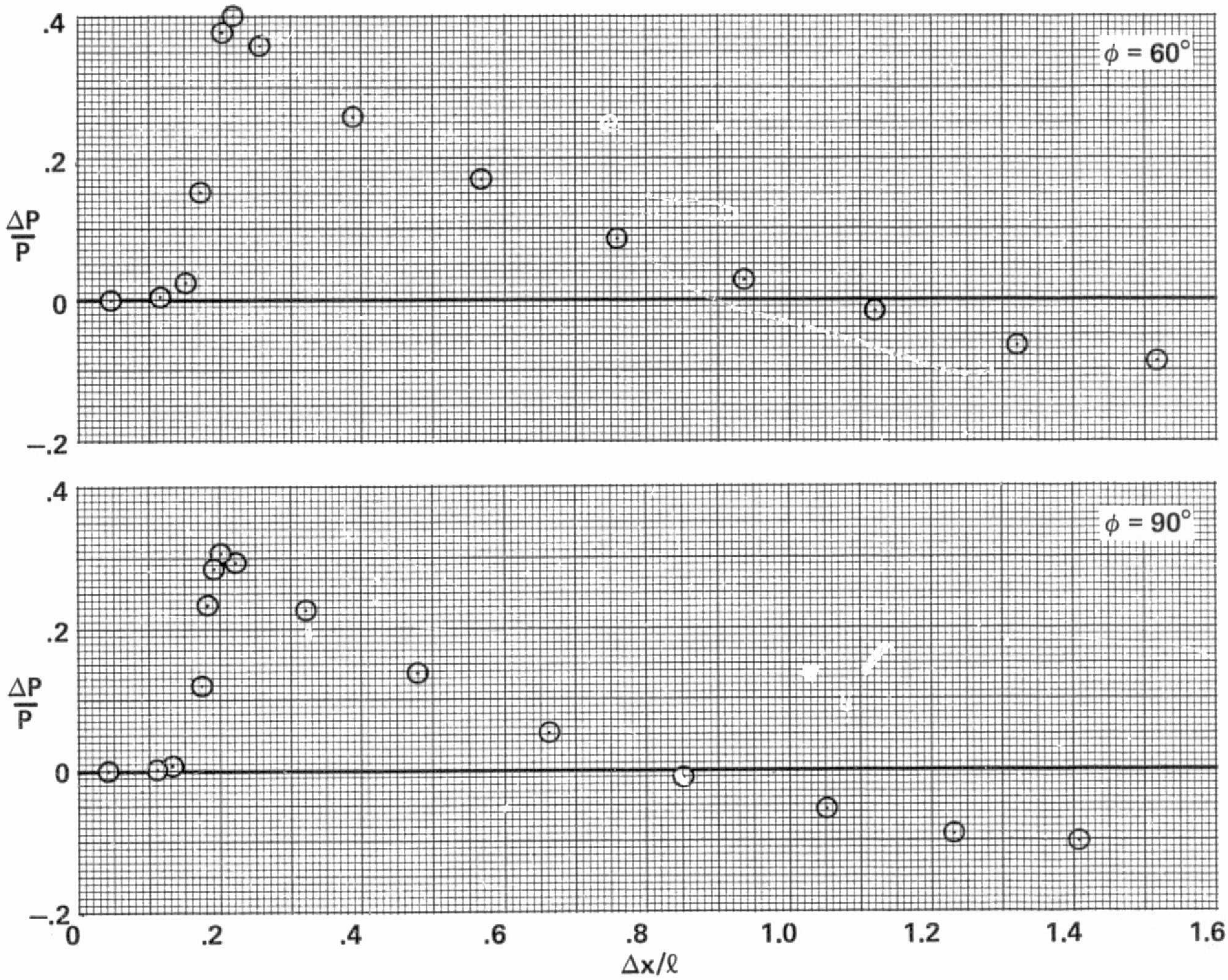
(c) ϕ = 120°

Figure 33.- Concluded.



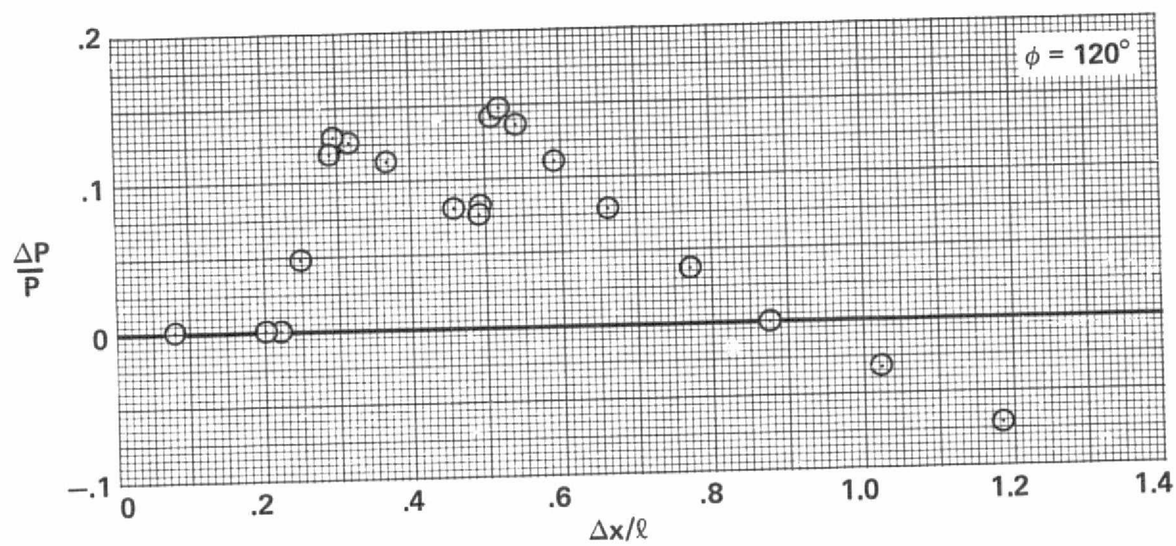
(a) ϕ = 0°, 30°

Figure 34.- Pressure signatures, M = 2.0, α = 20°, h/l = 1.55.



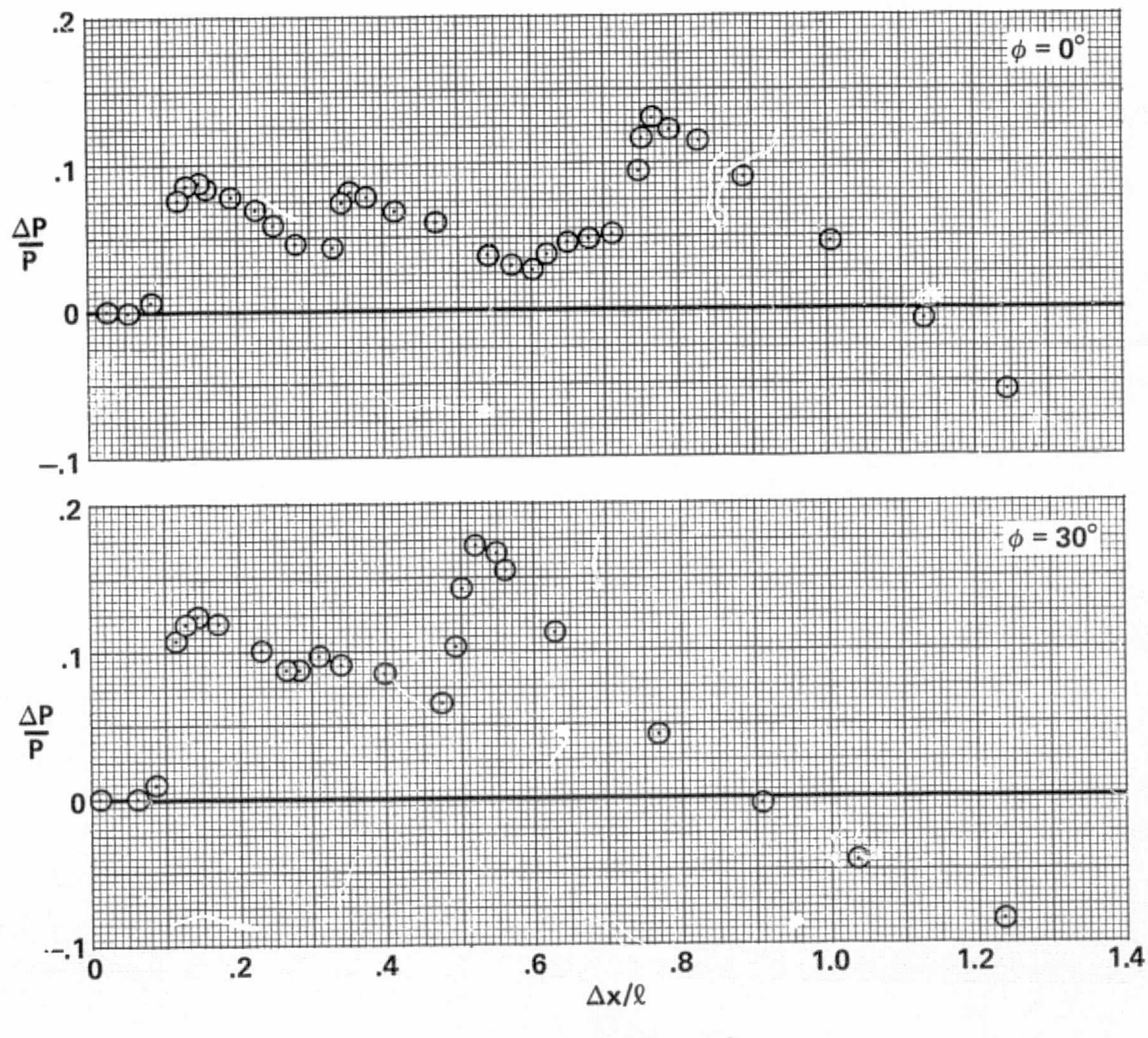
(b) ϕ = 60°, 90°

Figure 34.- Continued.



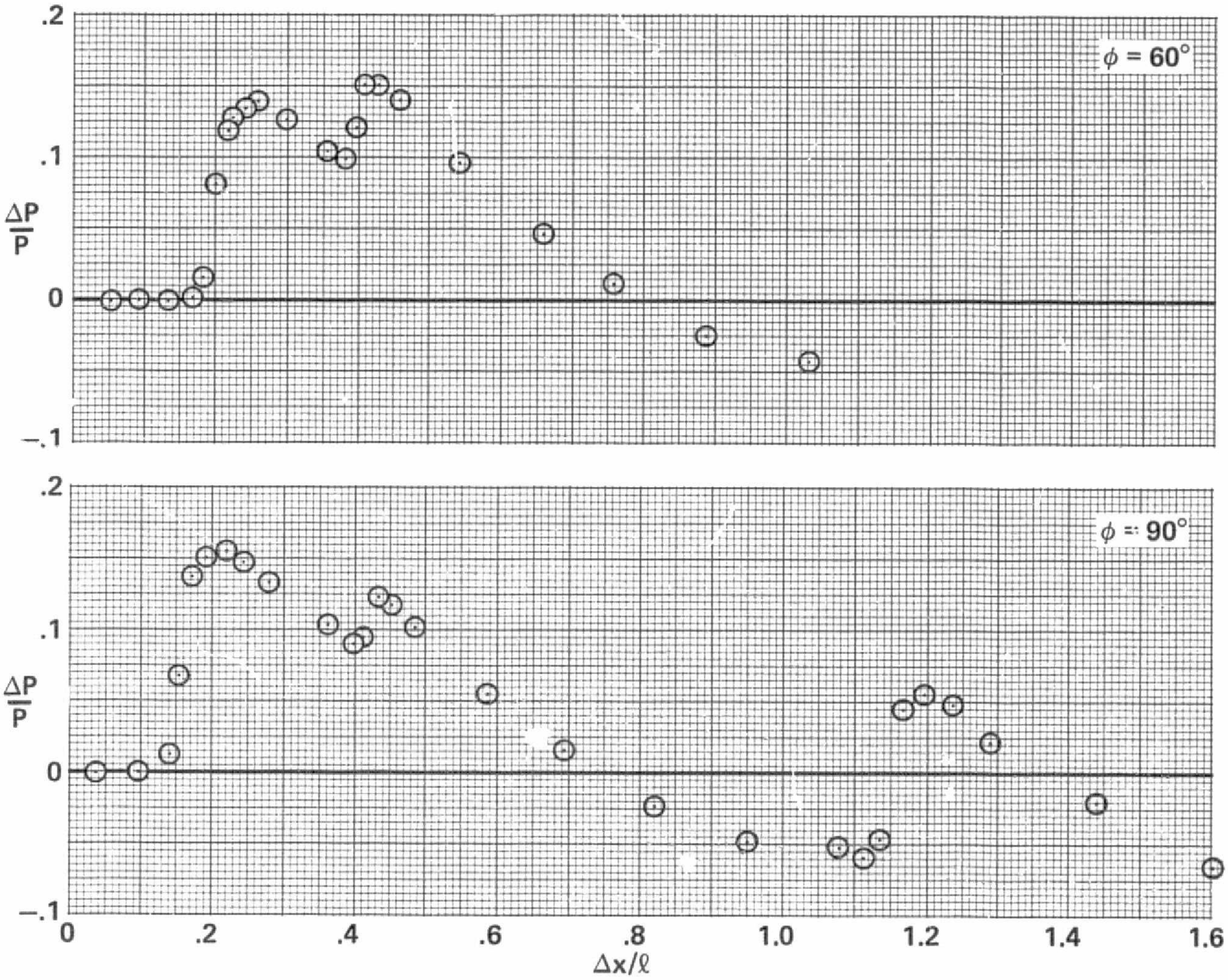
(c) ϕ = 120°

Figure 34.- Concluded.



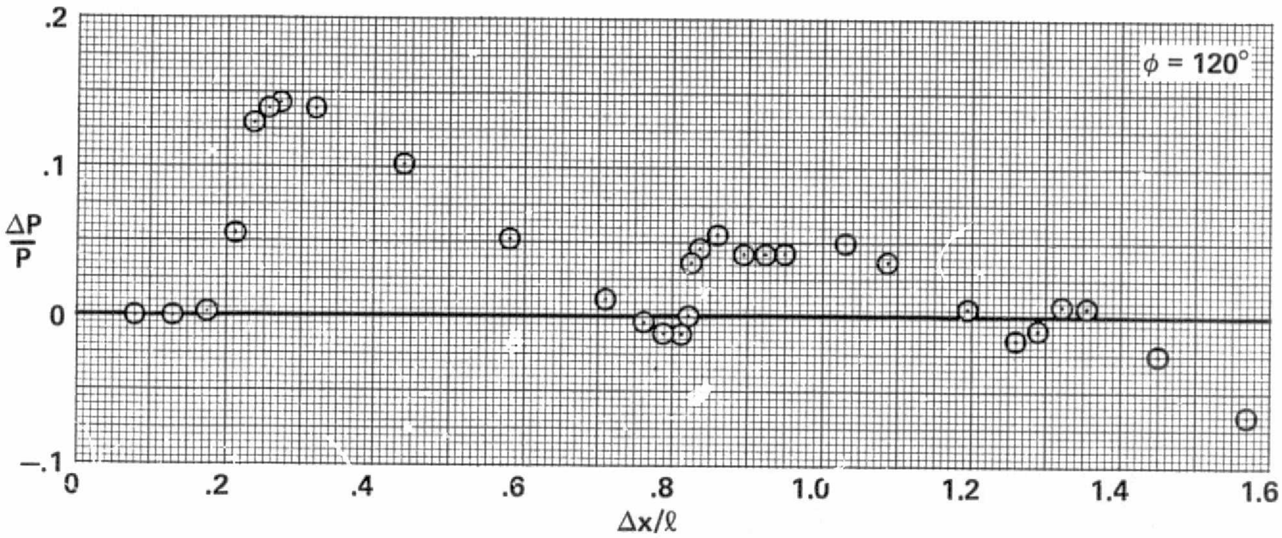
(a) $\phi = 0°, 30°$

Figure 35.- Pressure signatures, $M = 2.5$, $\alpha = 0°$, $h/l = 1.18$.



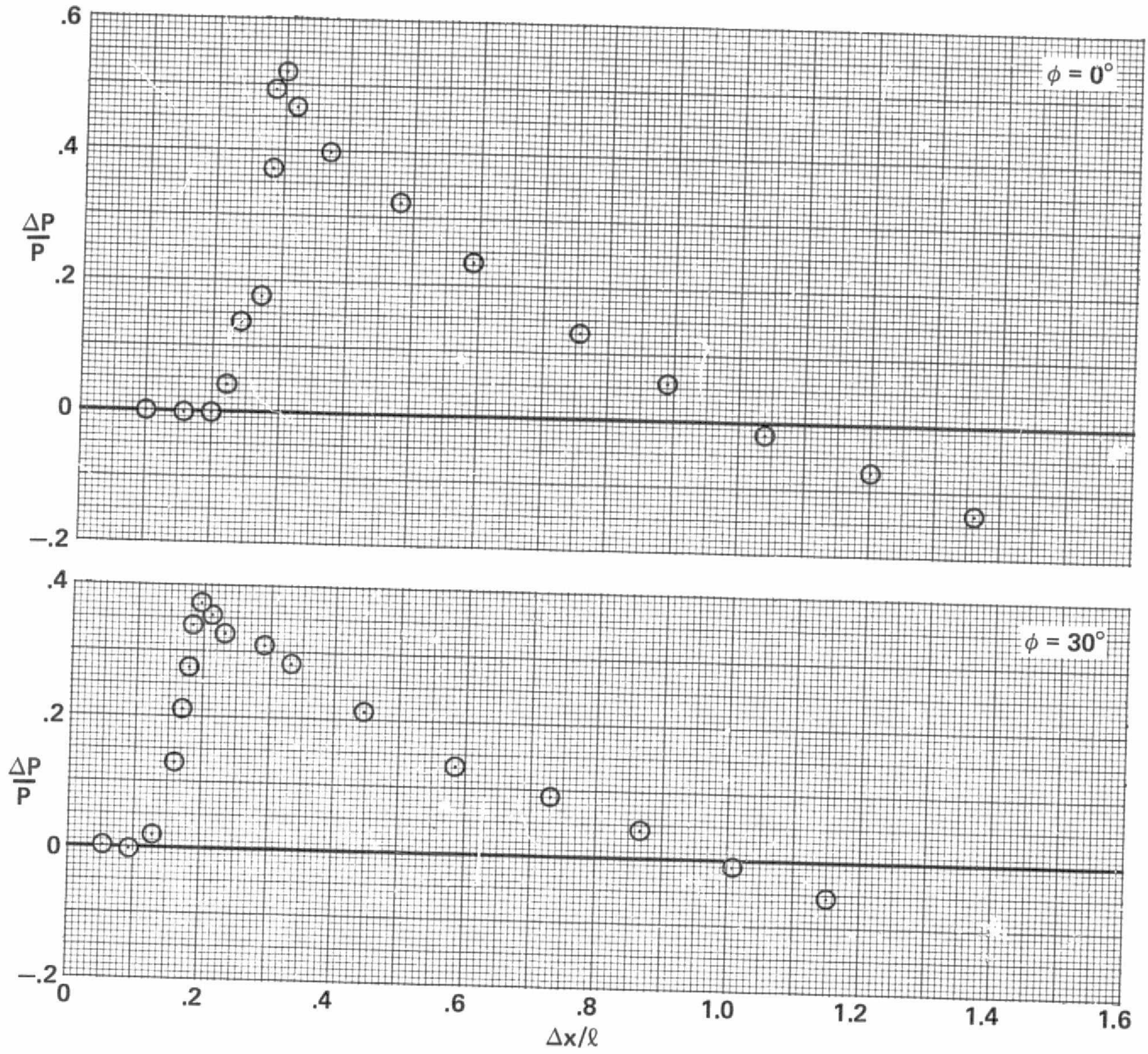
(b) ϕ = 60°, 90°

Figure 35.- Continued.



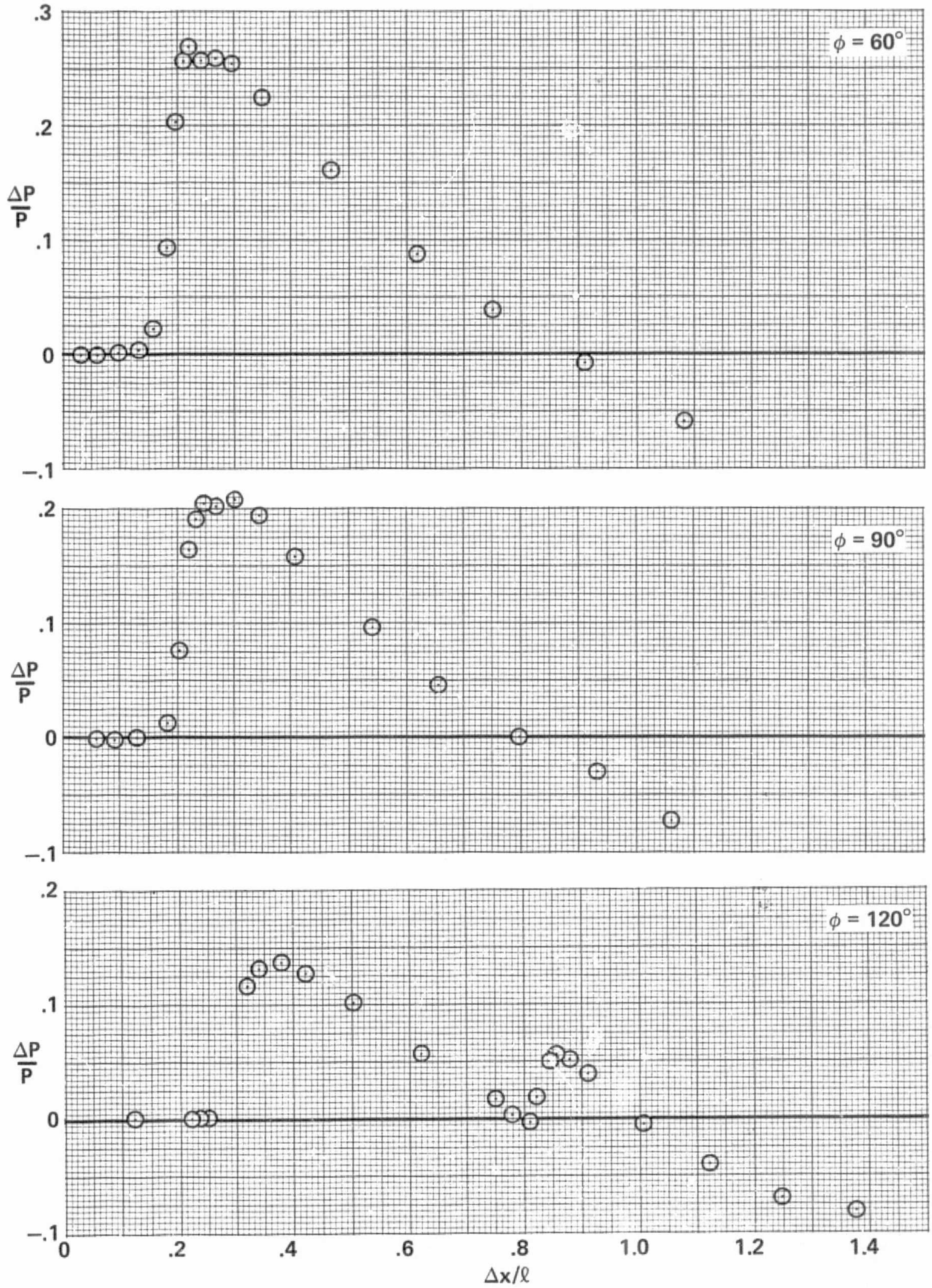
(c) ϕ = 120°

Figure 35.- Concluded.



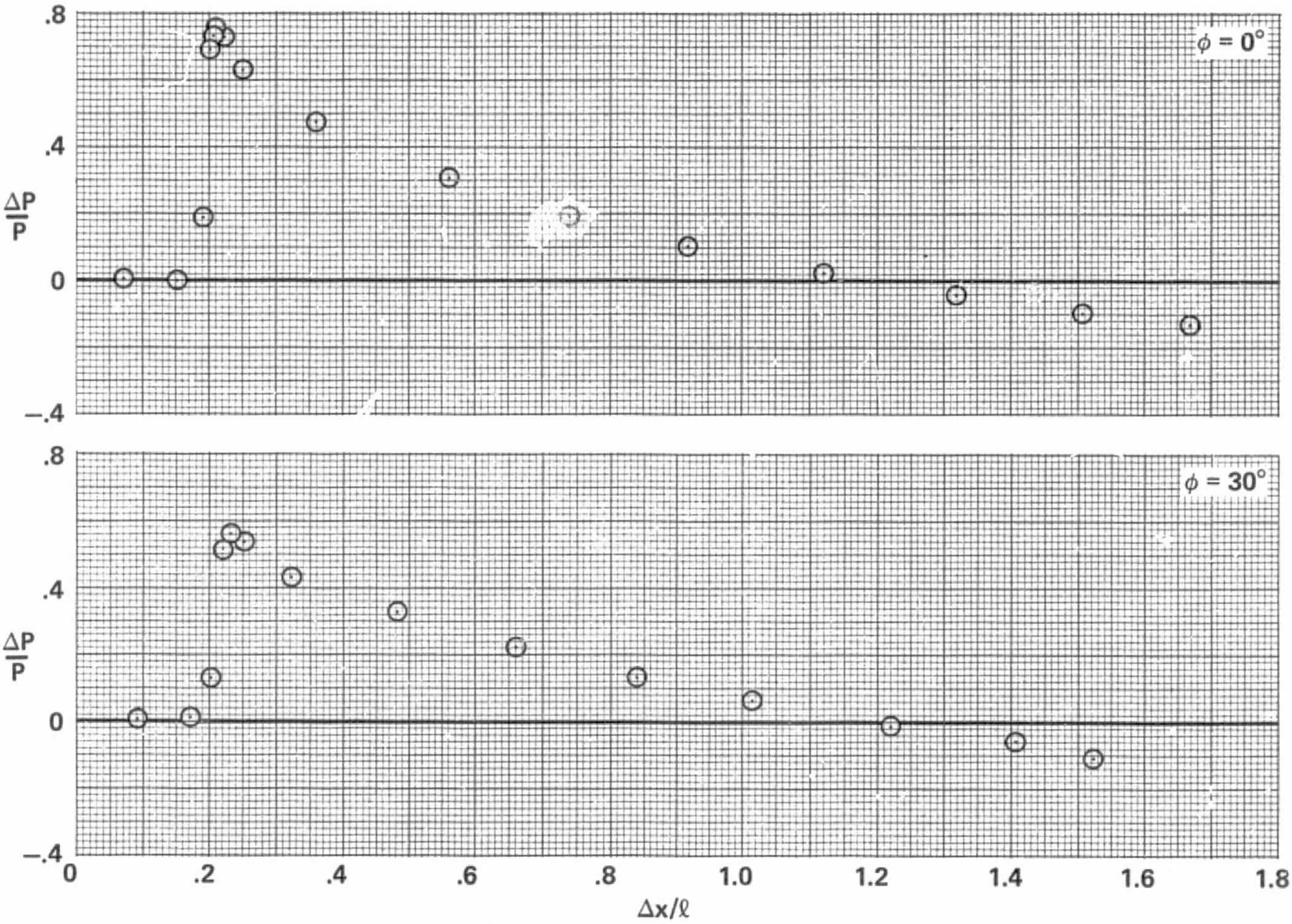
(a) ϕ = 0°, 30°

Figure 36.- Pressure signatures, M = 2.5, α = 10°, h/l = 1.18.



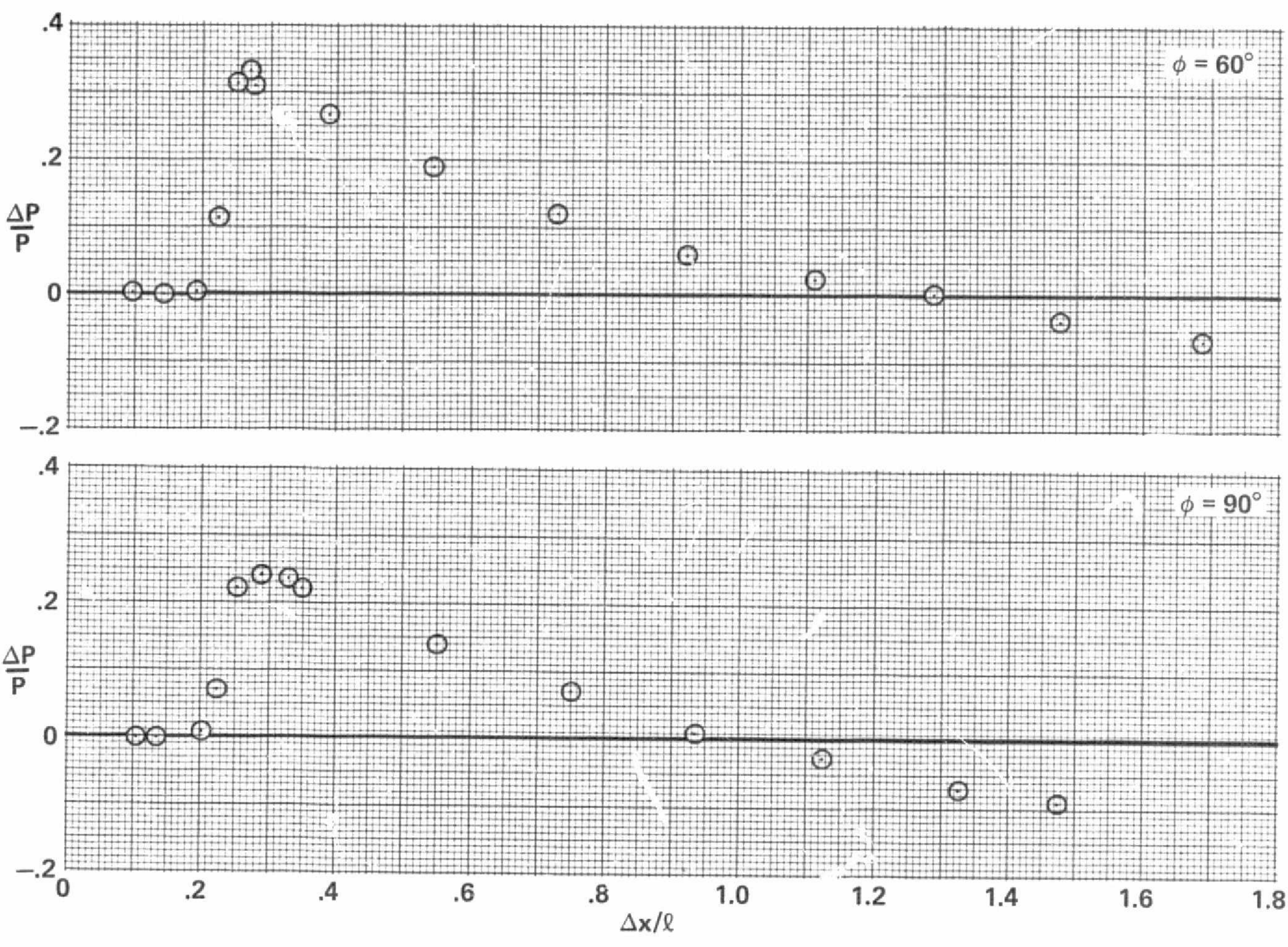
(b) ϕ = 60°, 90°, 120°

Figure 36.- Concluded.



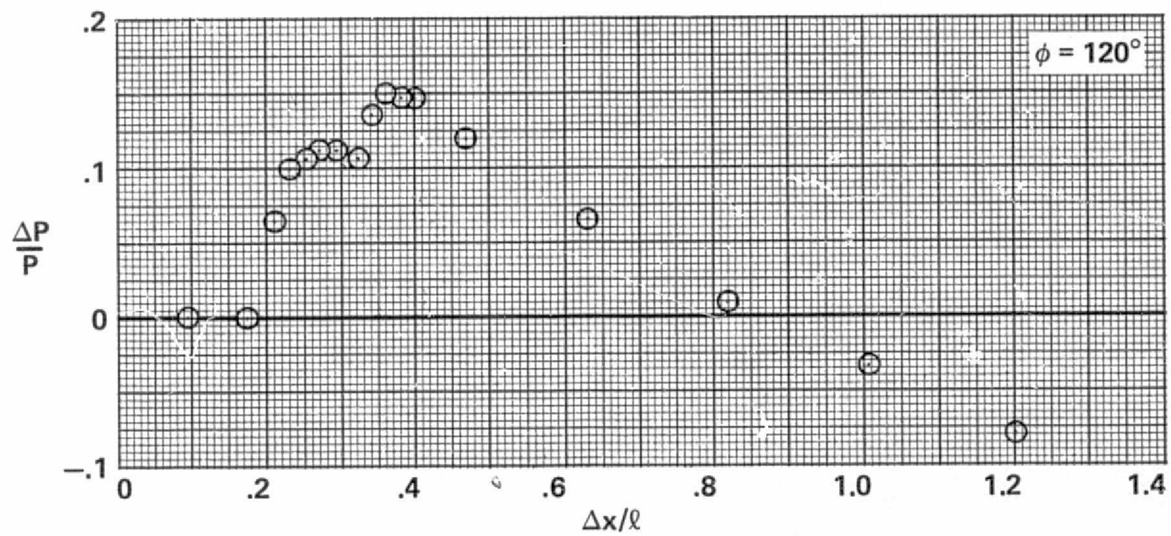
(a) $\phi = 0°, 30°$

Figure 37.- Pressure signatures, $M = 2.5$, $\alpha = 20°$, $h/l = 1.55$.



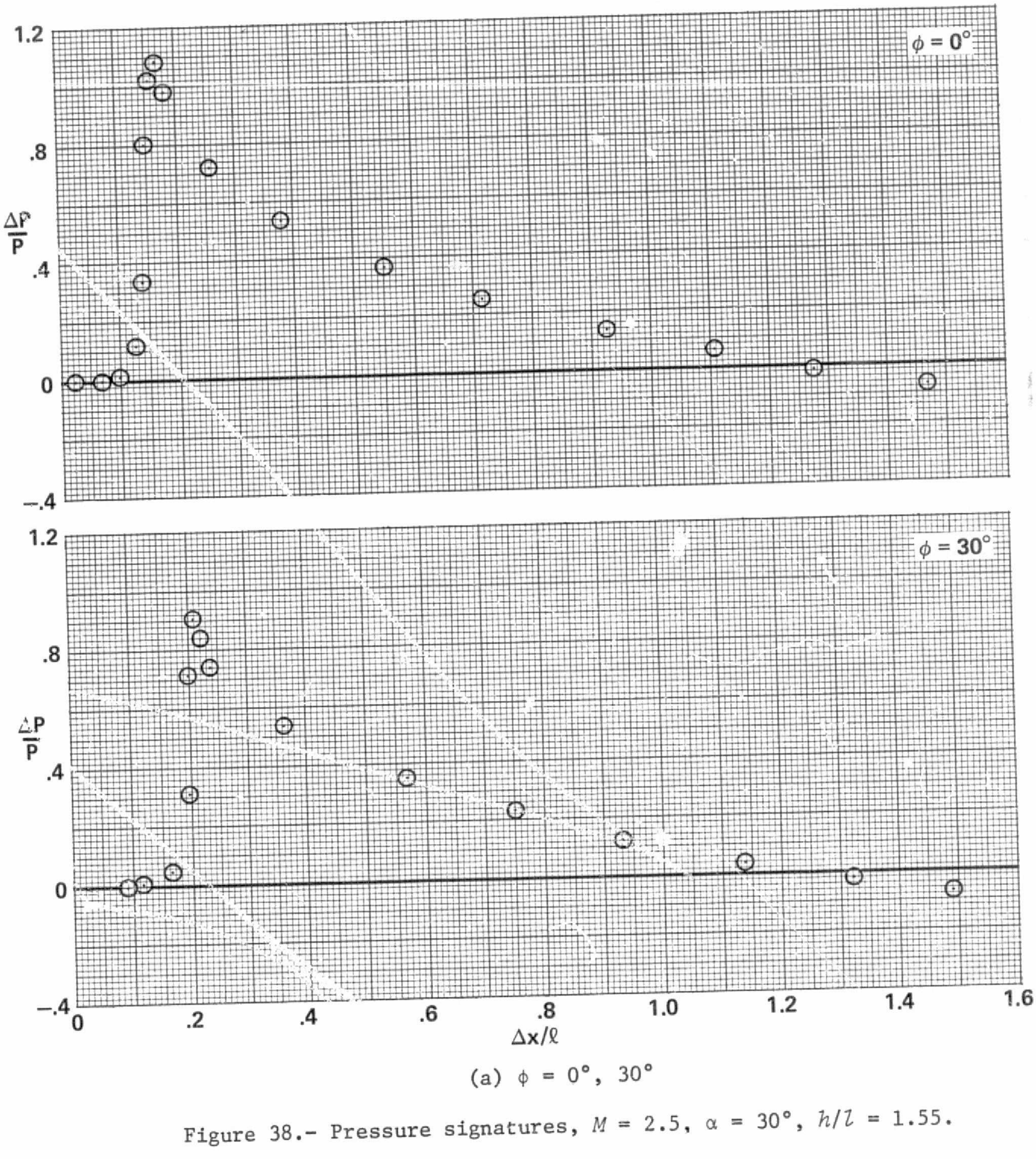
(b) ϕ = 60°, 90°

Figure 37.- Continued.



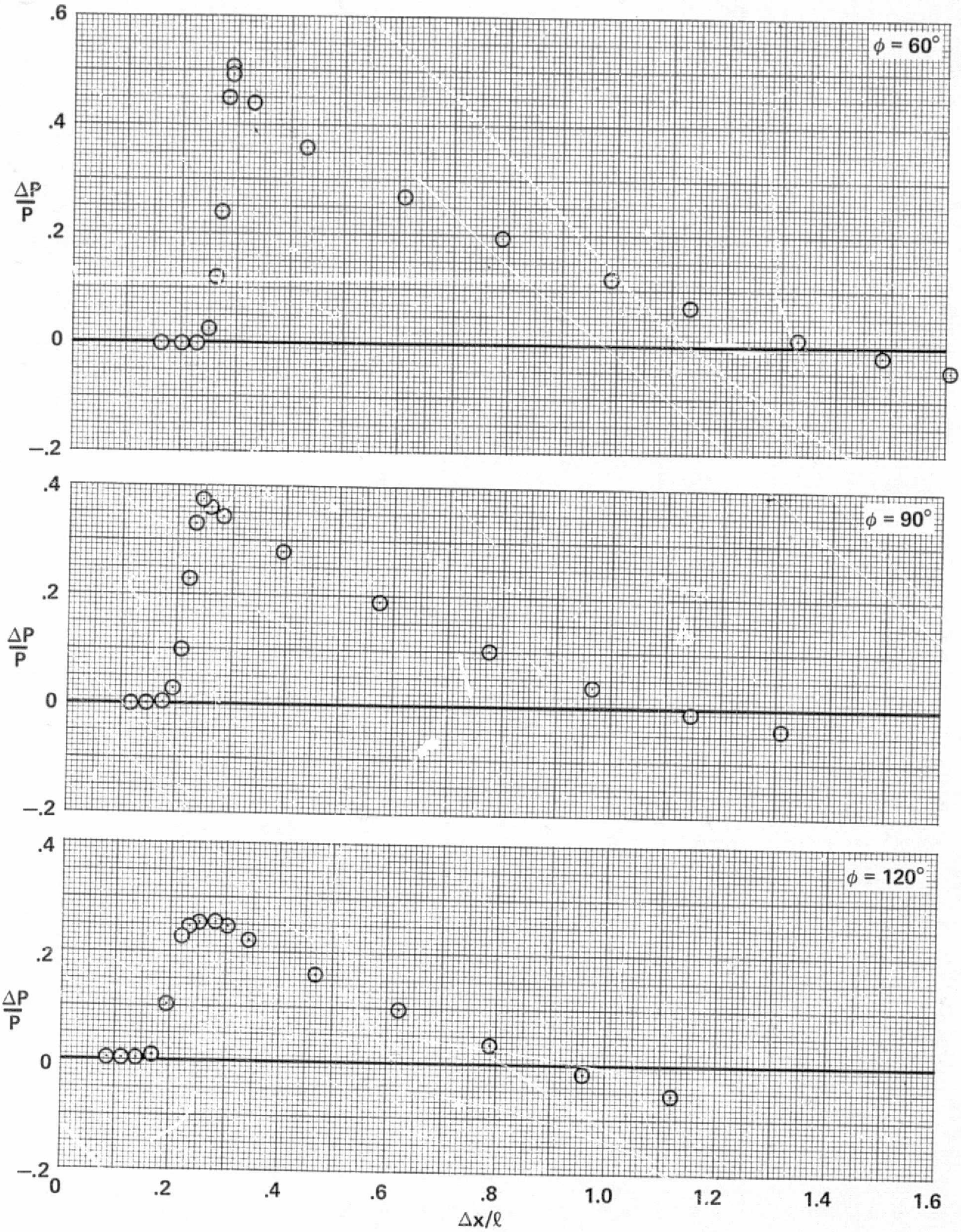
(c) ϕ = 120°

Figure 37.- Concluded.



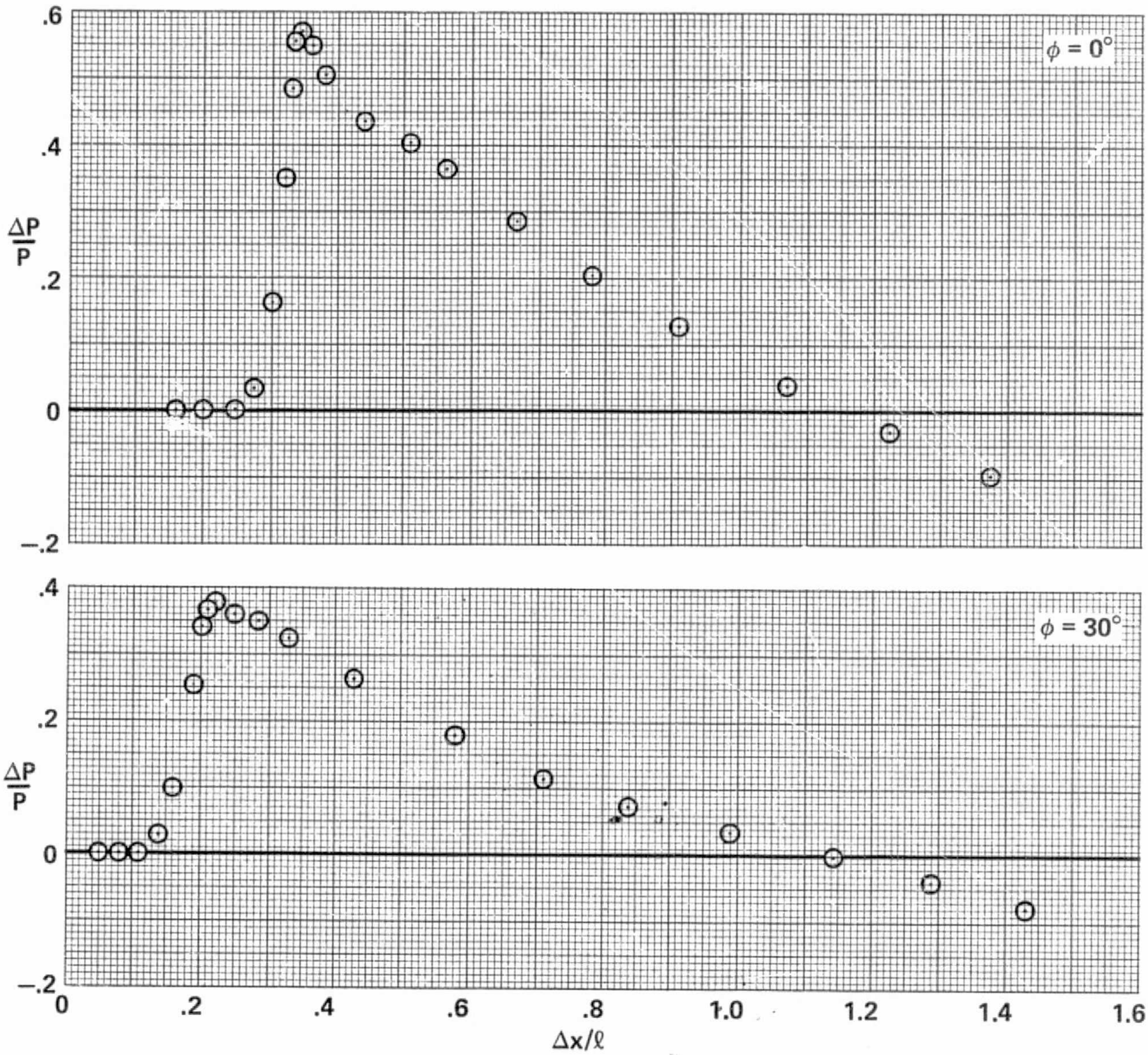
(a) ϕ = 0°, 30°

Figure 38.- Pressure signatures, M = 2.5, α = 30°, h/l = 1.55.



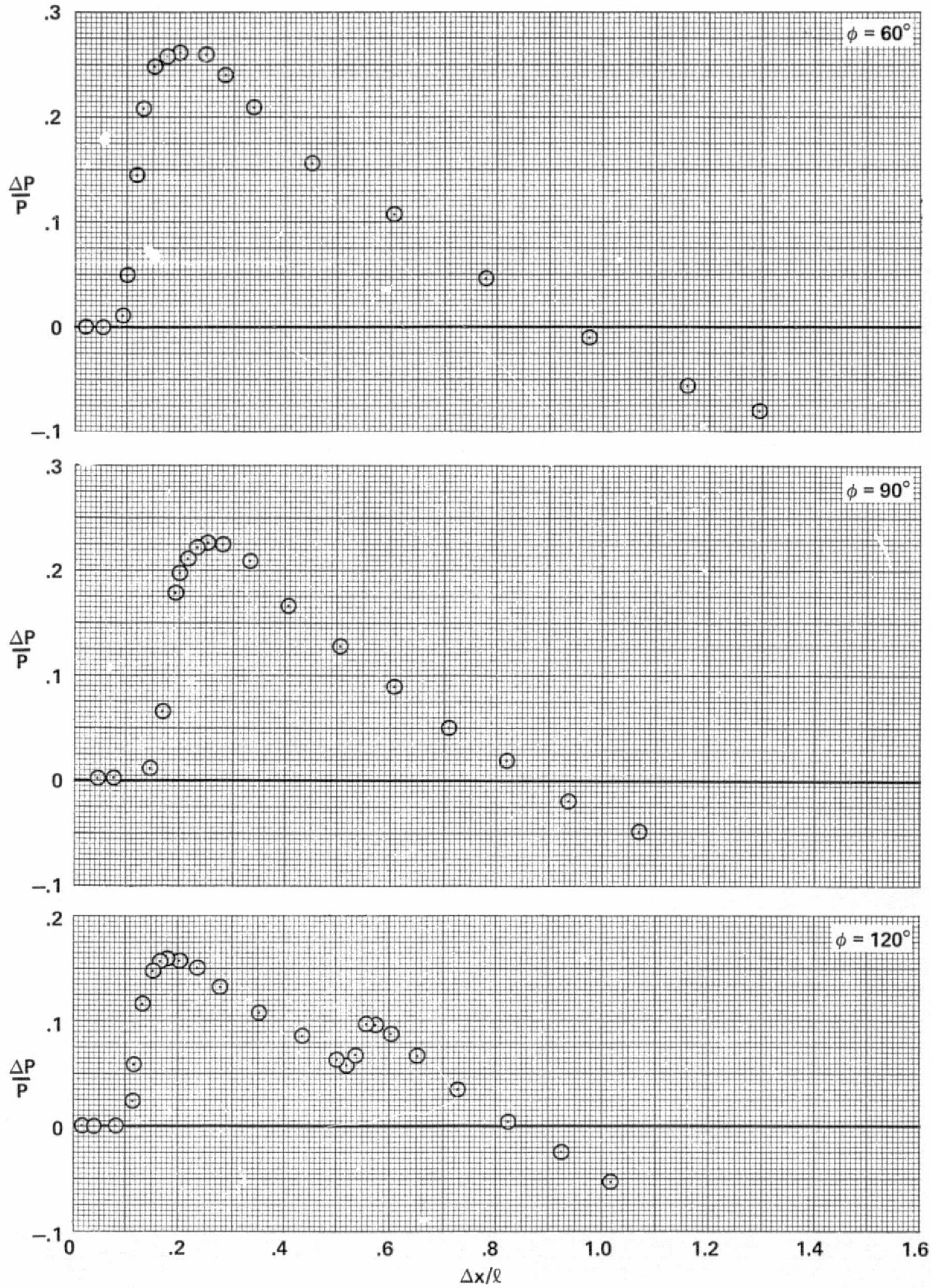
(b) ϕ = 60°, 90°, 120°

Figure 38.- Concluded.



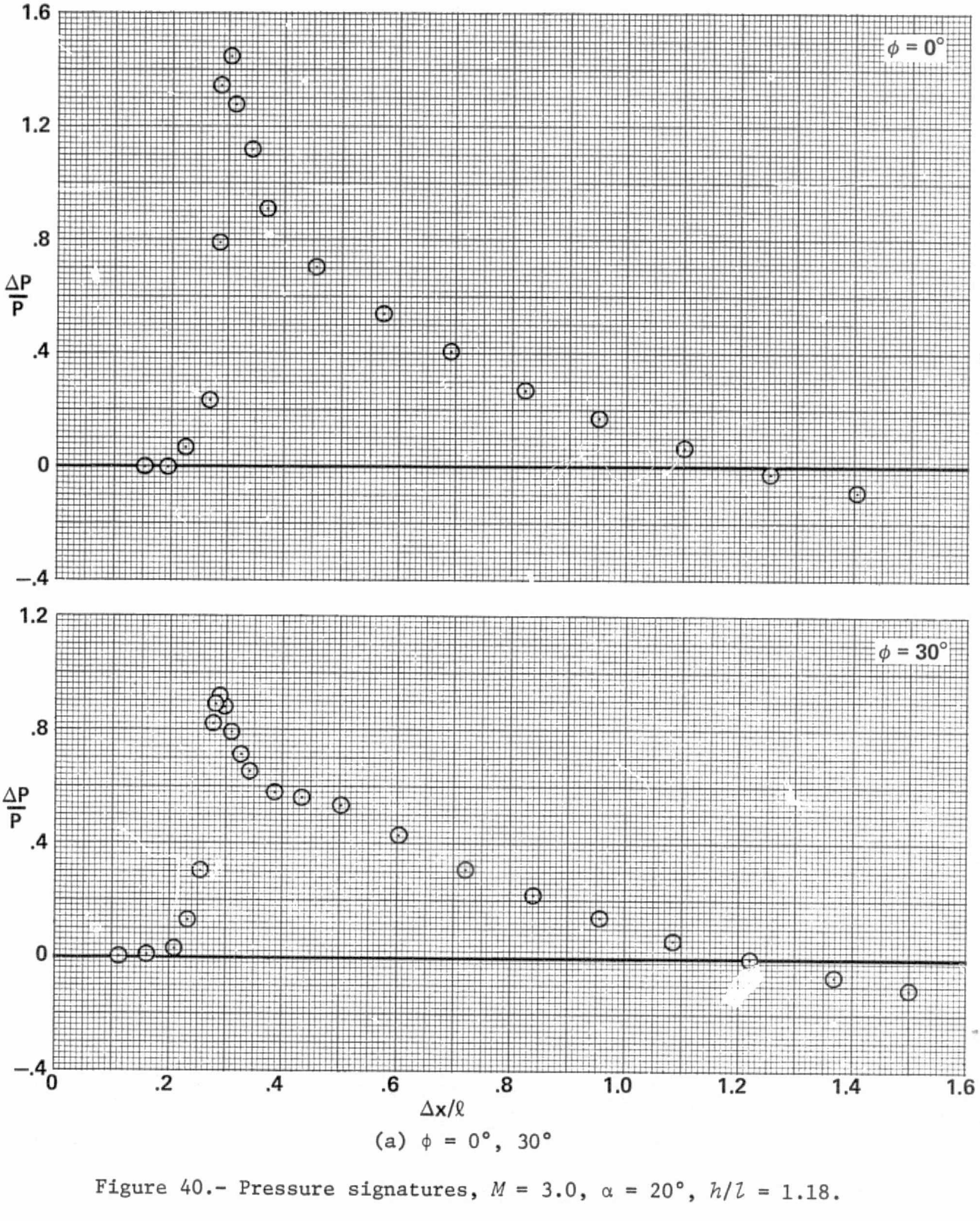
(a) $\phi = 0°, 30°$

Figure 39.- Pressure signatures, $M = 3.0$, $\alpha = 10°$, $h/l = 1.18$.



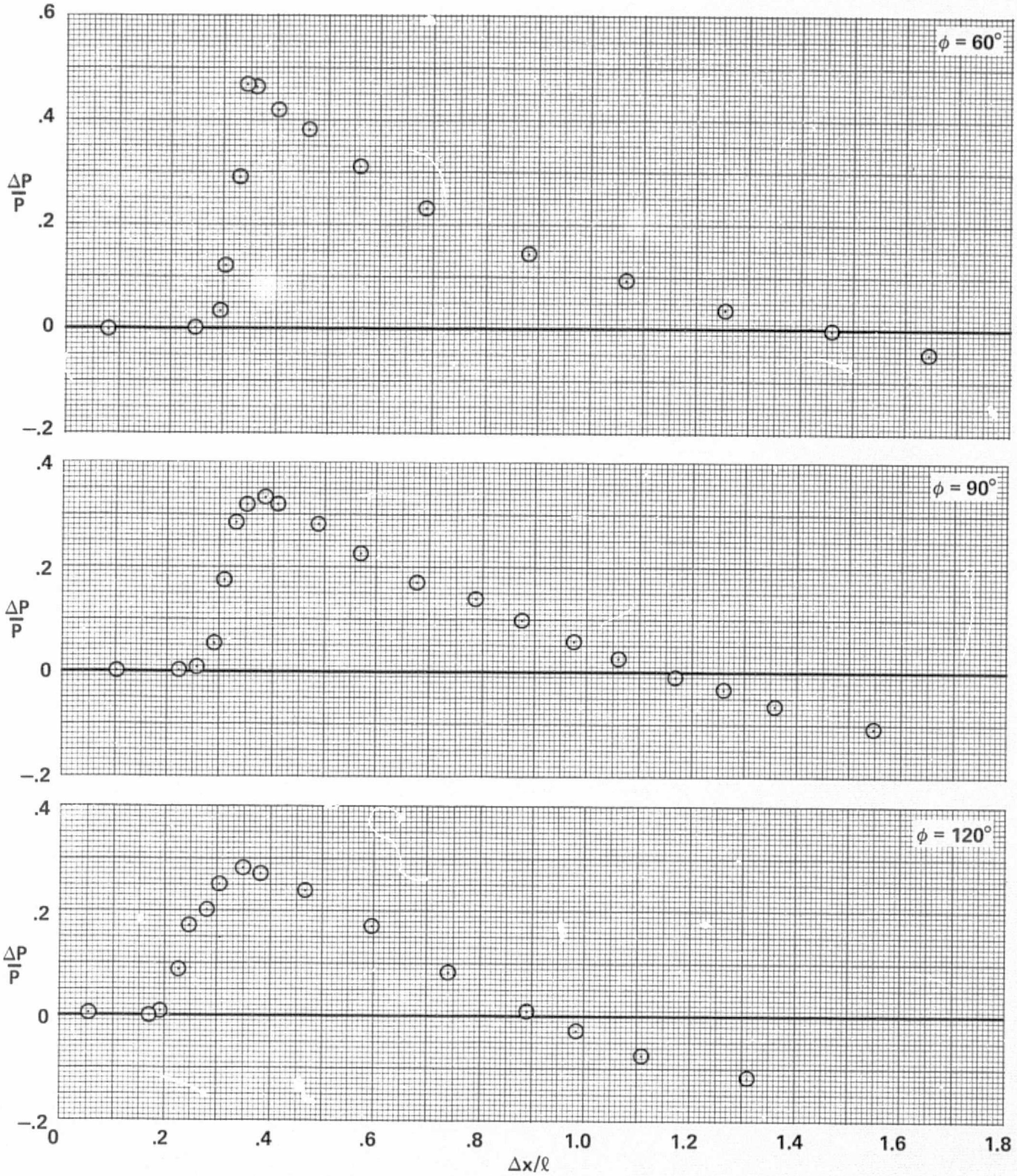
(b) ϕ = 60°, 90°, 120°

Figure 39.- Concluded.



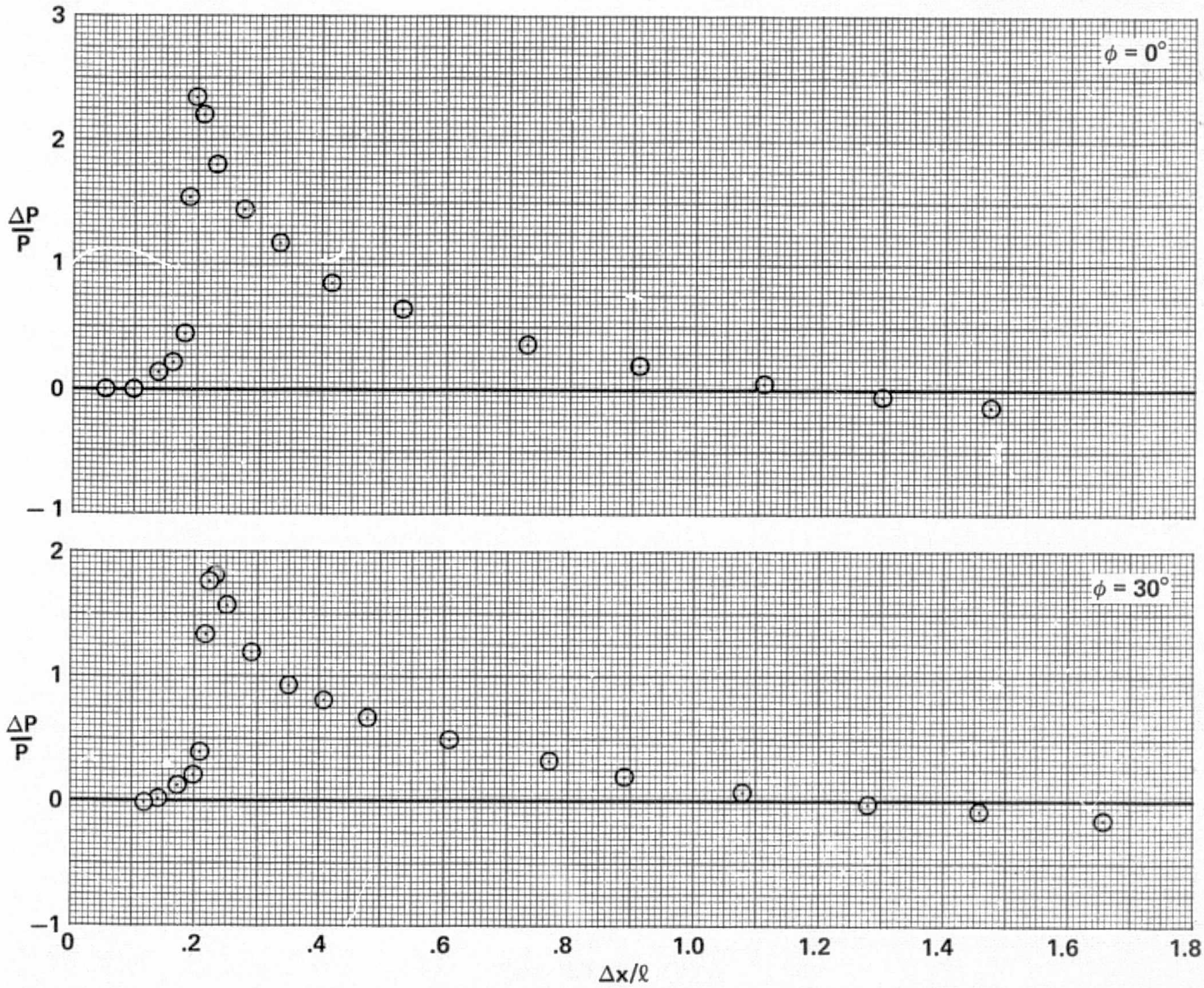
(a) ϕ = 0°, 30°

Figure 40.- Pressure signatures, M = 3.0, α = 20°, h/l = 1.18.



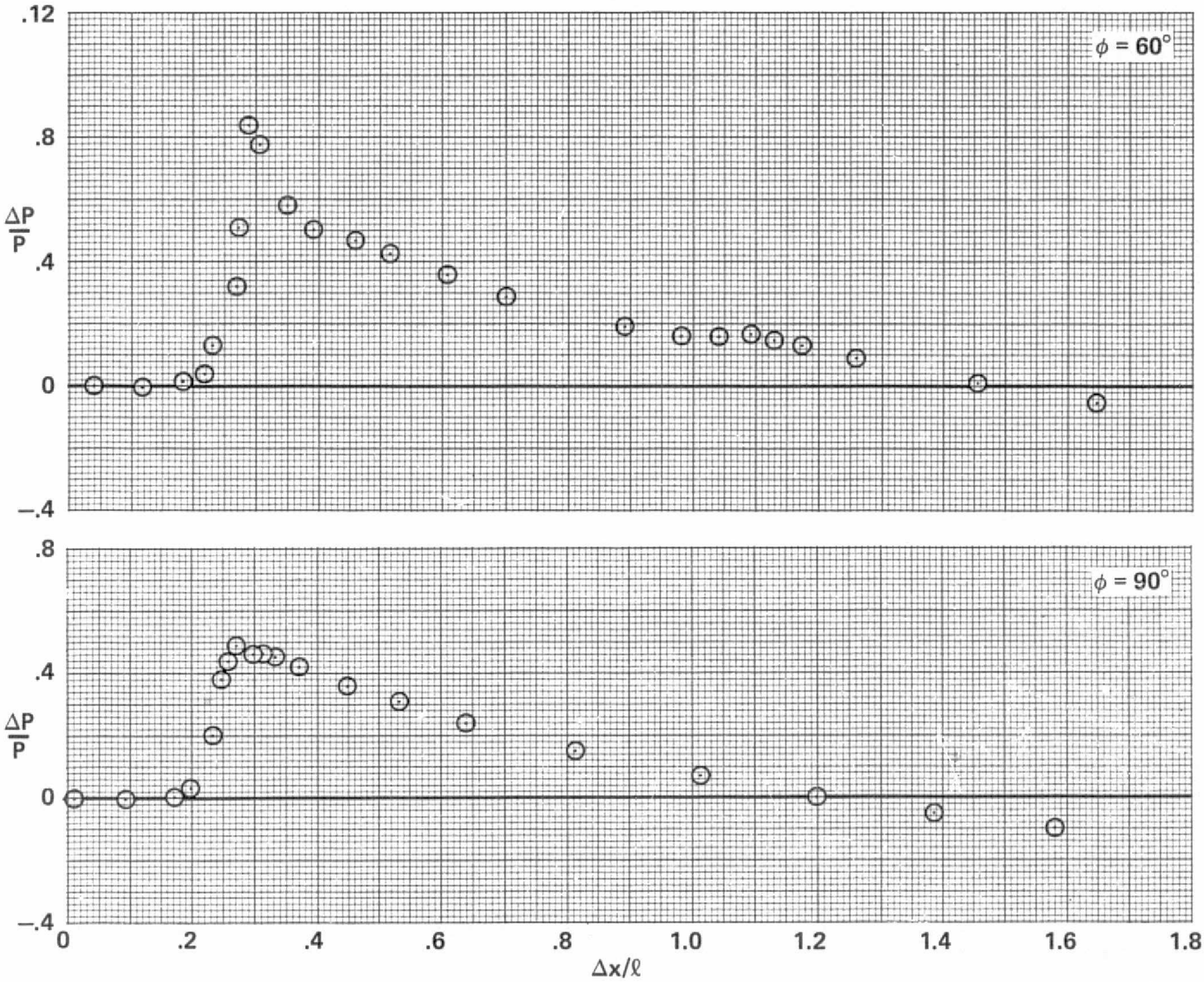
(b) ϕ = 60°, 90°, 120°

Figure 40.- Concluded.



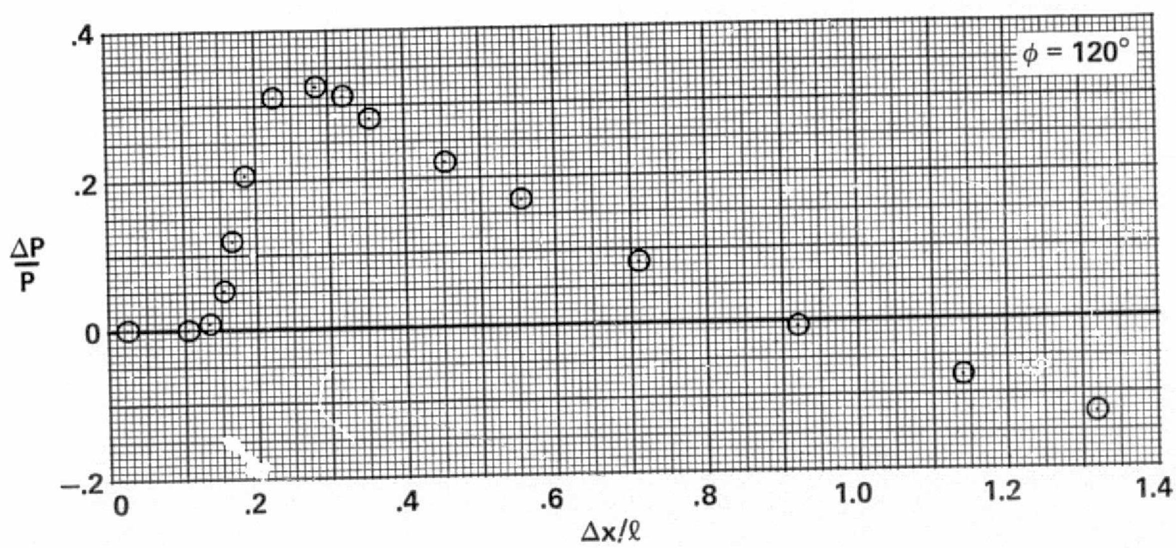
(a) $\phi = 0°, 30°$

Figure 41.- Pressure signatures, $M = 3.0$, $\alpha = 30°$, $h/l = 1.18$.



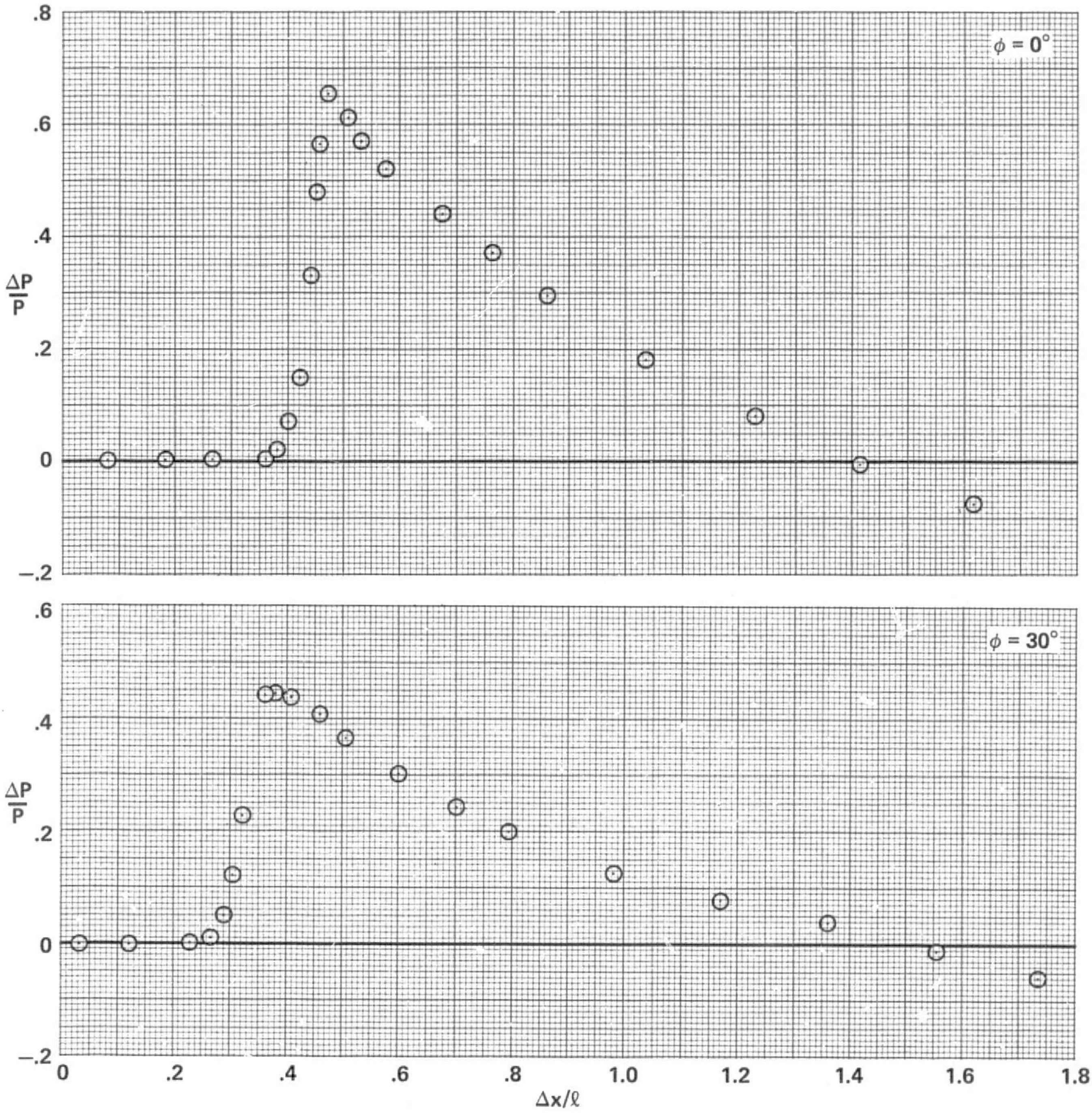
(b) ϕ = 60°, 90°

Figure 41.- Continued.



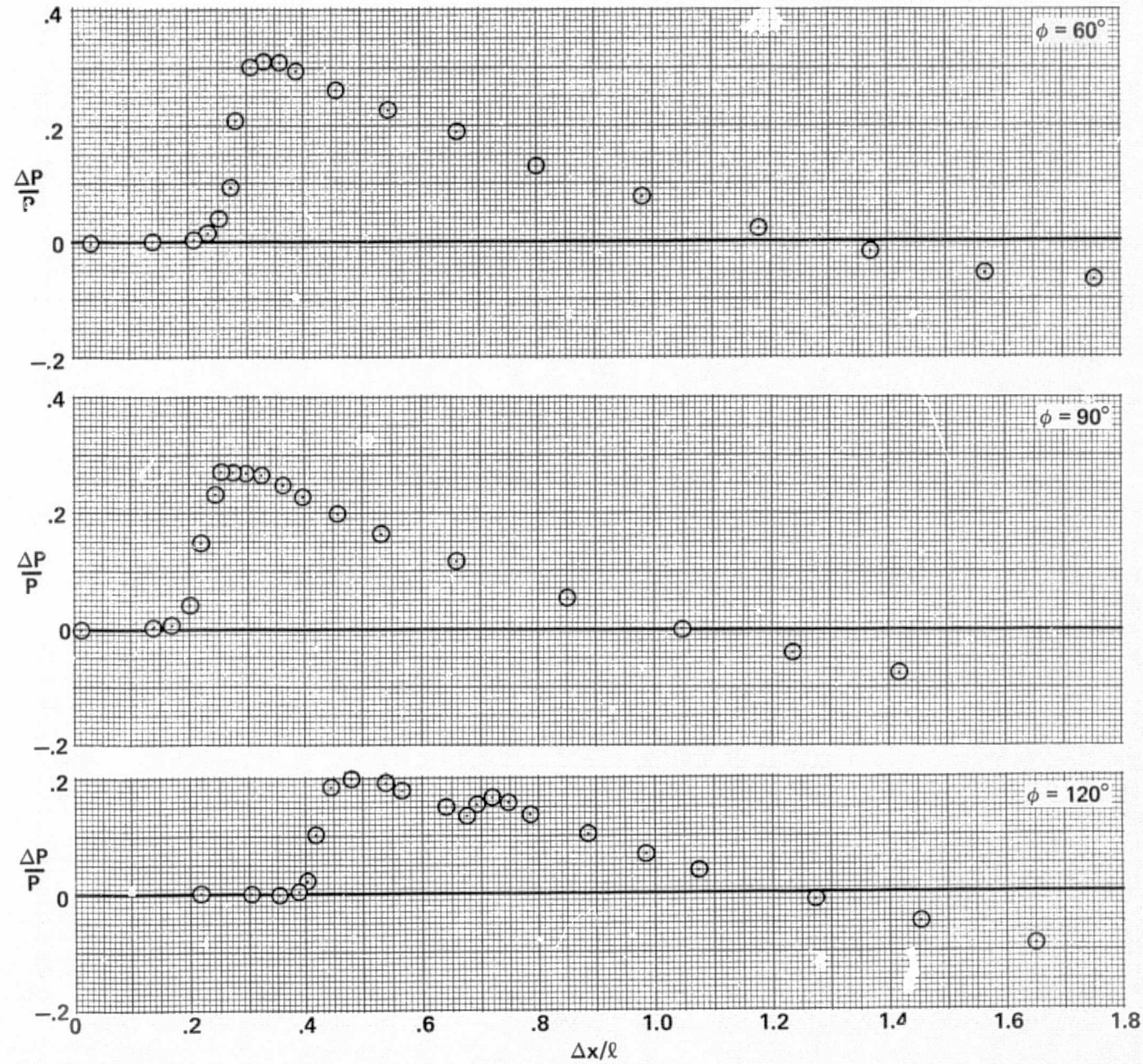
(c) ϕ = 120°

Figure 41.- Concluded.



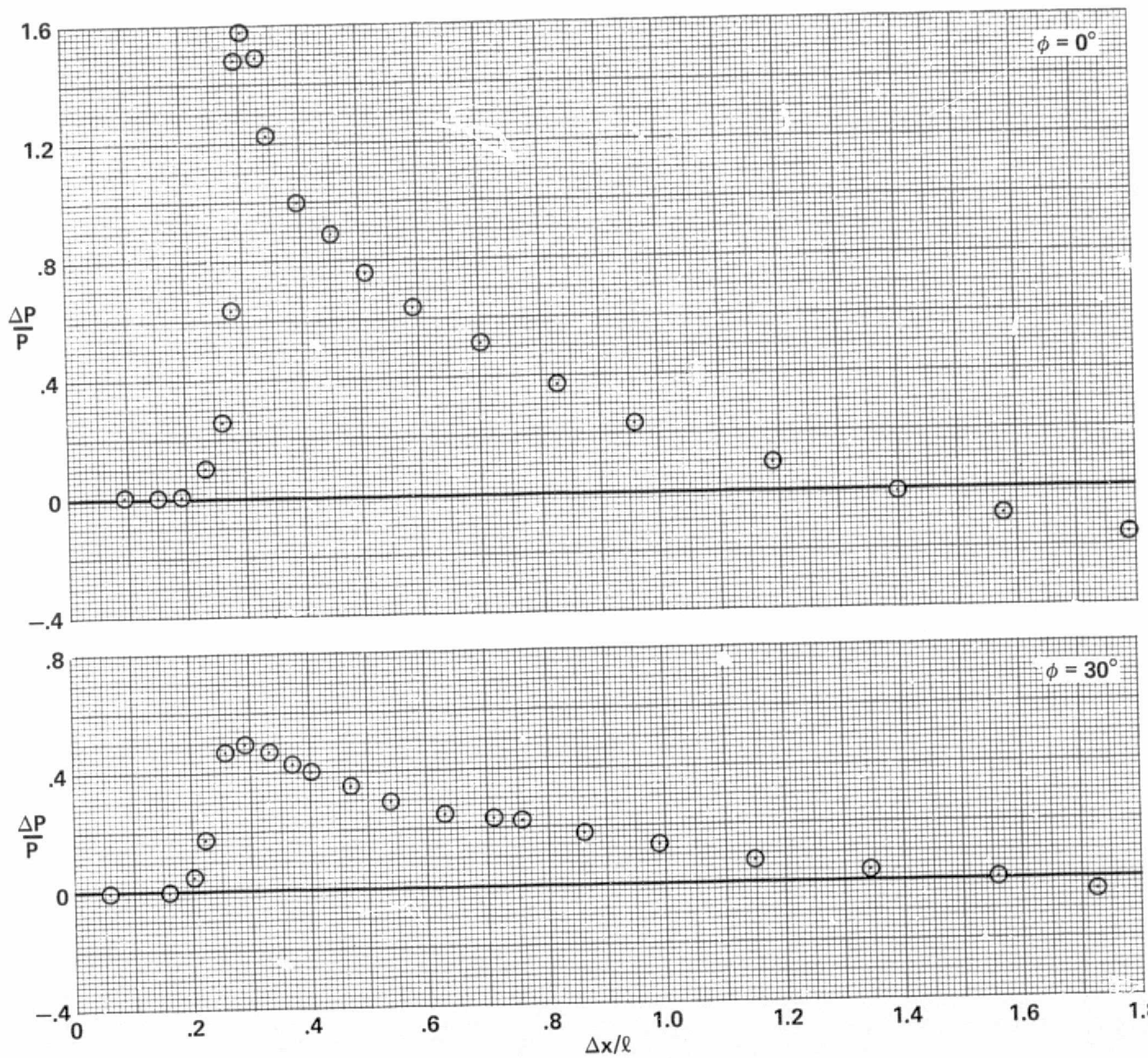
(a) ϕ = 0°, 30°

Figure 42.- Pressure signatures, $M = 3.5$, $\alpha = 10°$, $h/l = 1.18$.



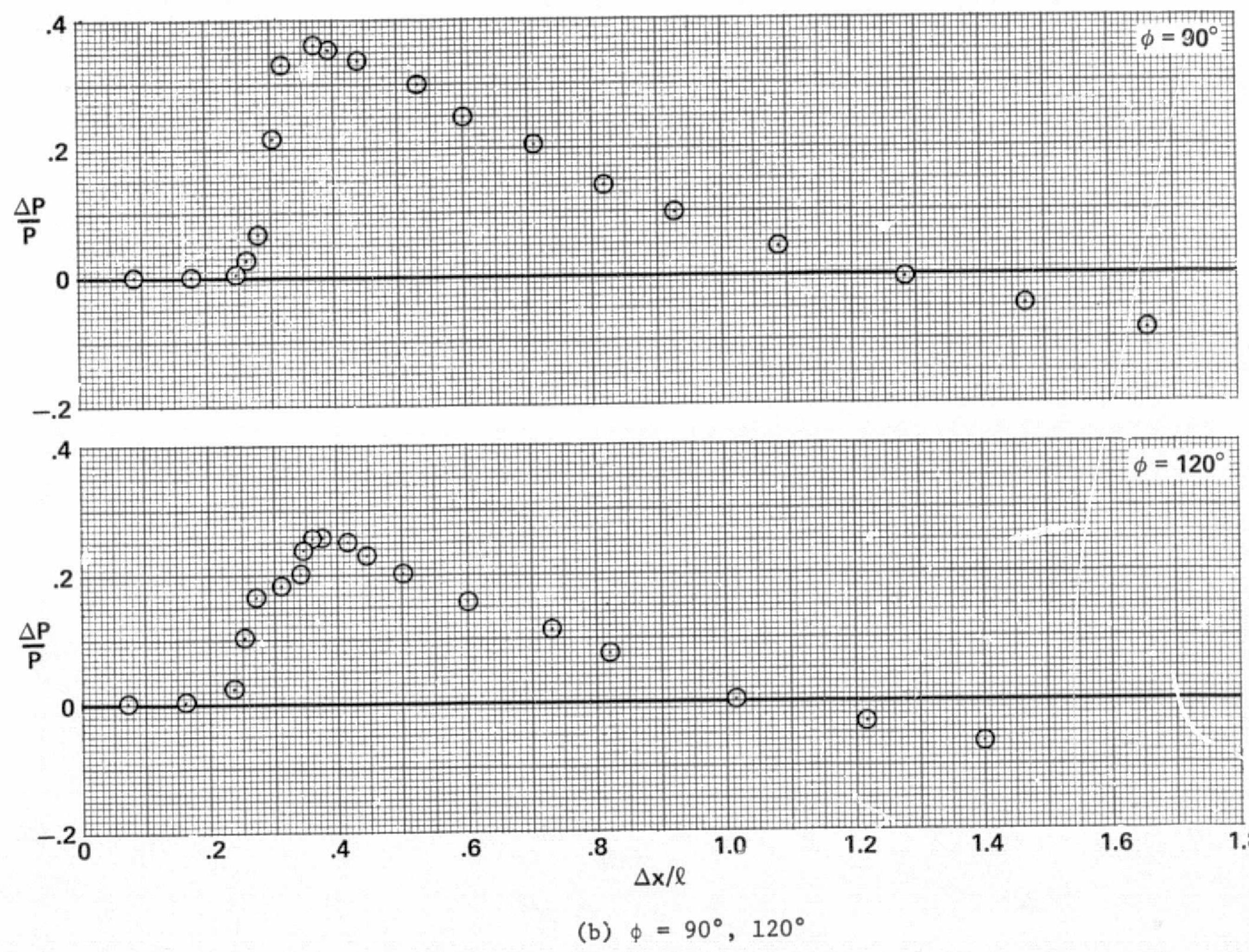
(b) ϕ = 60°, 90°, 120°

Figure 42.- Concluded.



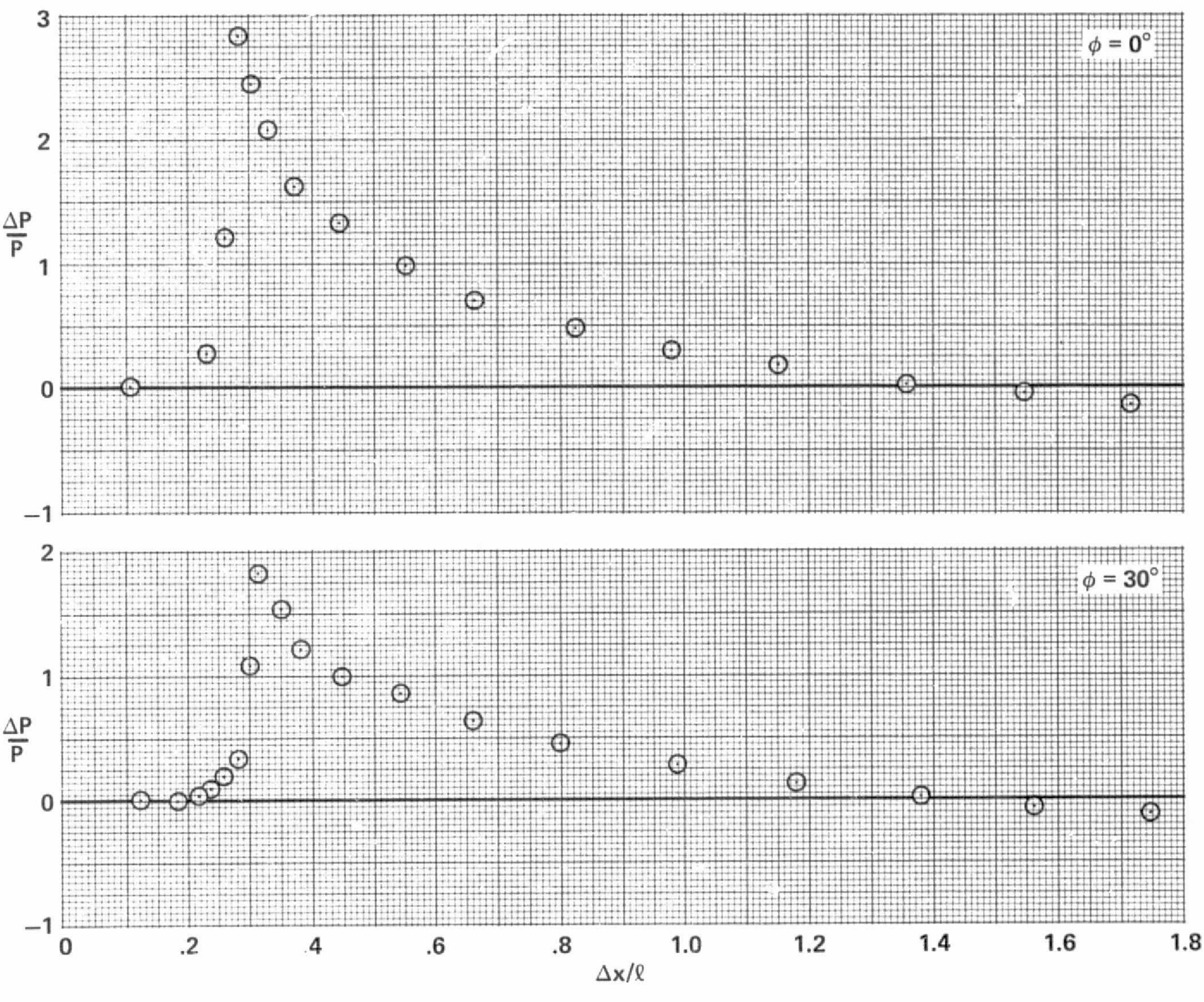
(a) $\phi = 0°, 30°$

Figure 43.- Pressure signatures, $M = 3.5$, $\alpha = 20°$, $h/l = 1.18$.



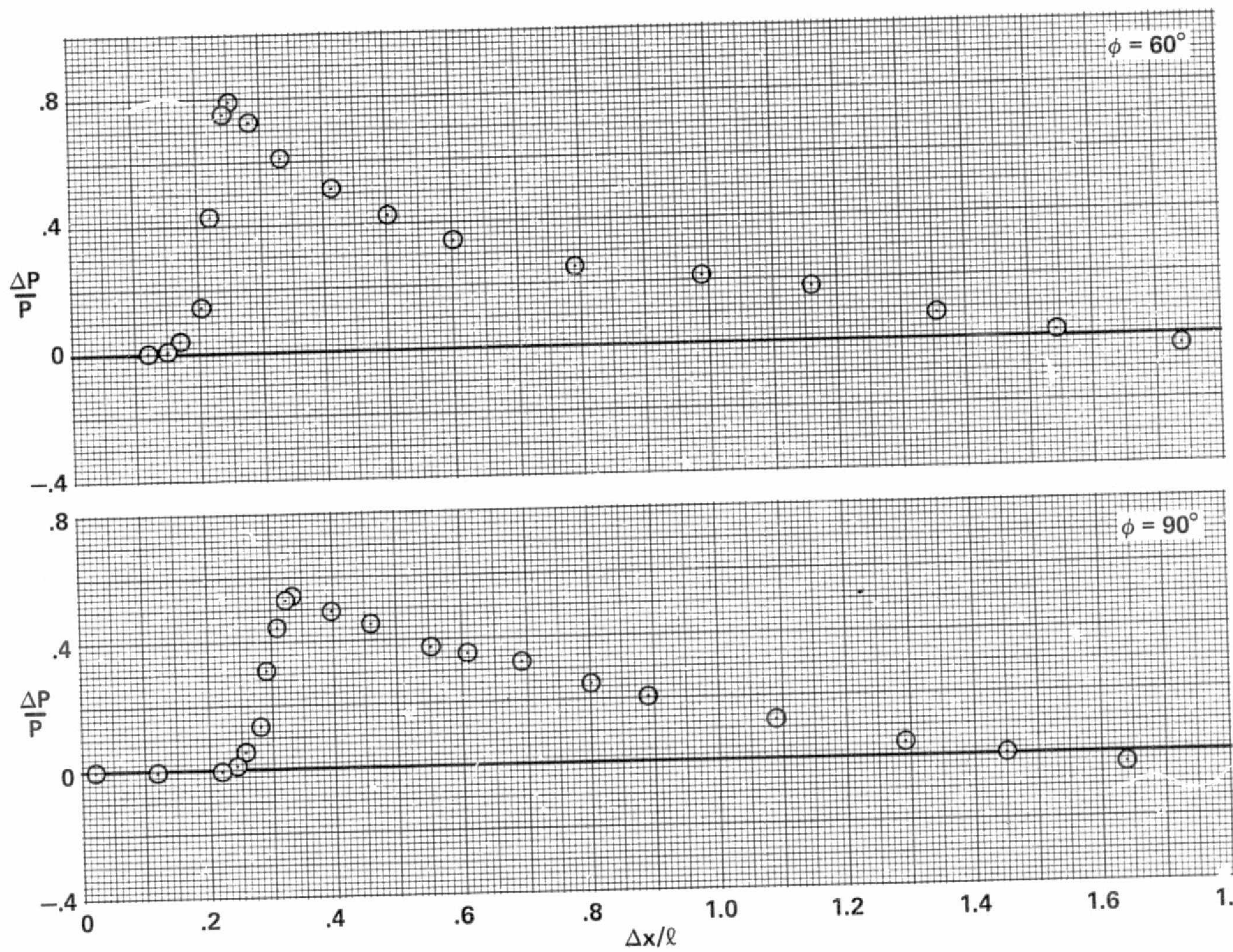
(b) ϕ = 90°, 120°

Figure 43.- Concluded.



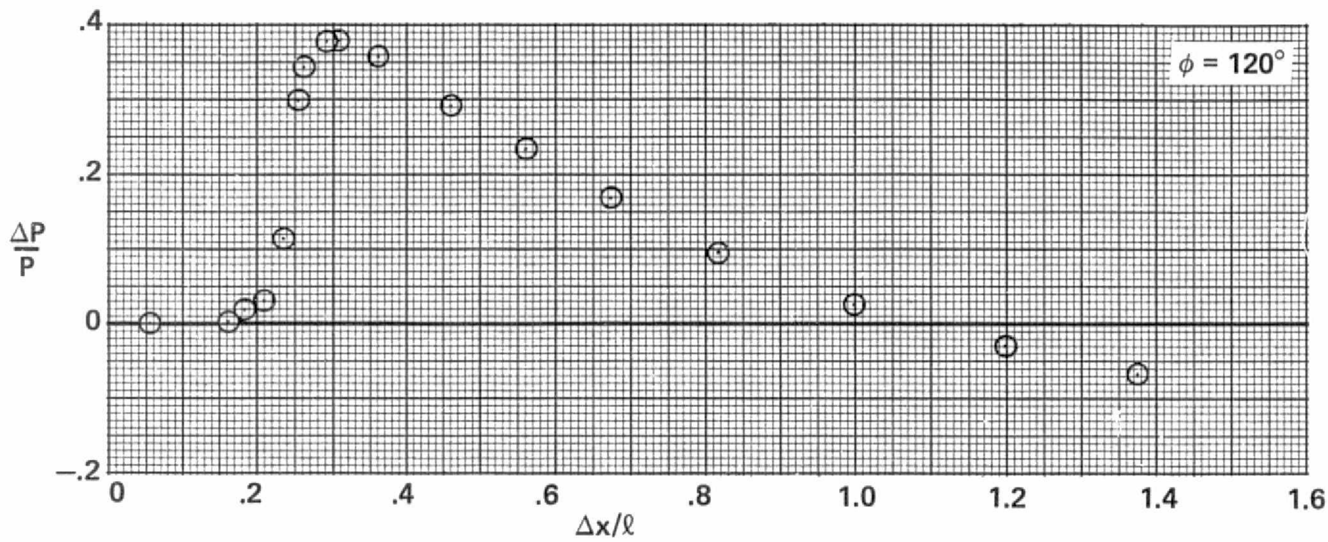
(a) ϕ = 0°, 30°

Figure 44.- Pressure signatures, M = 3.5, α = 30°, h/l = 1.18.



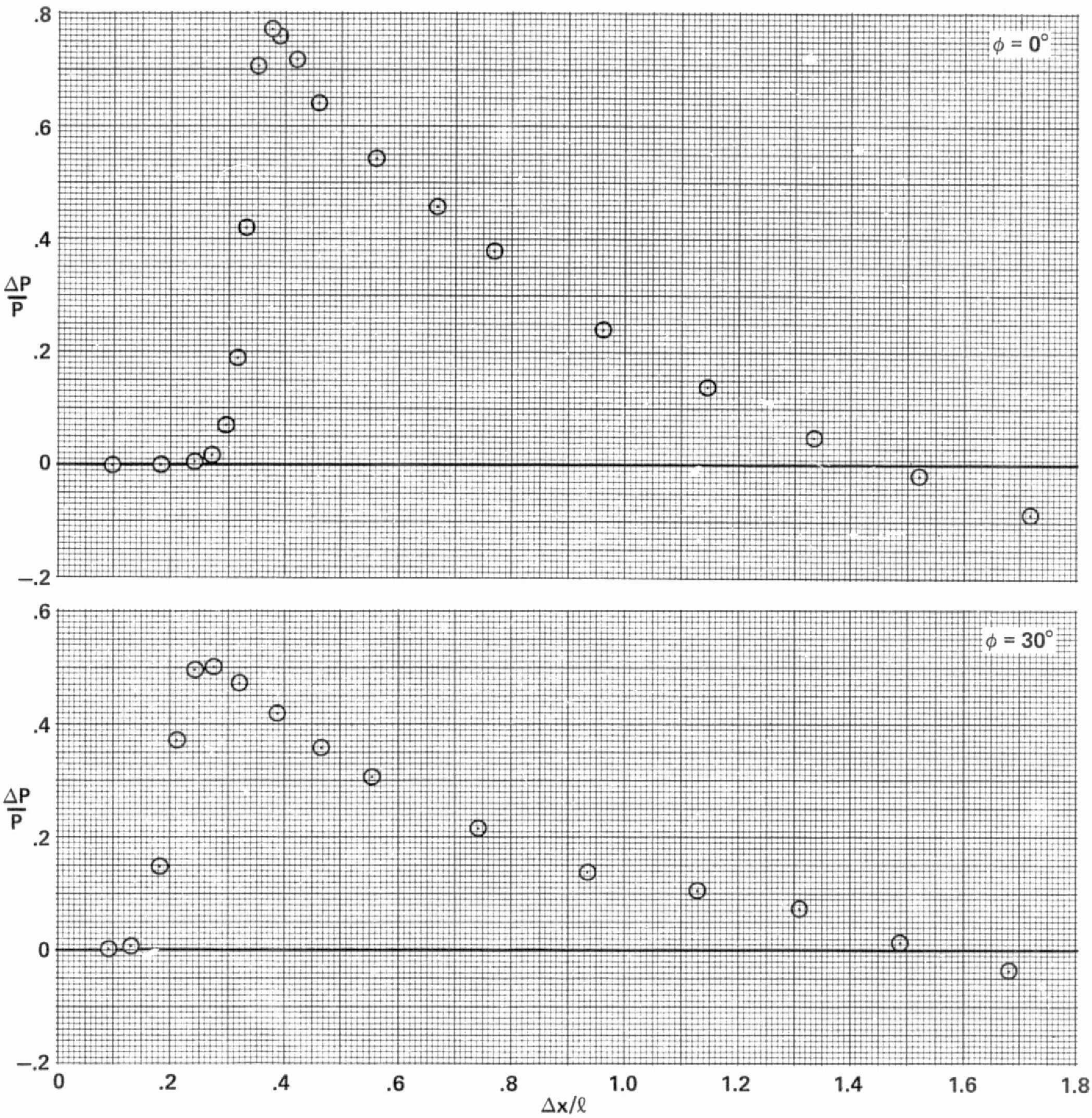
(b) ϕ = 60°, 90°

Figure 44.- Continued.



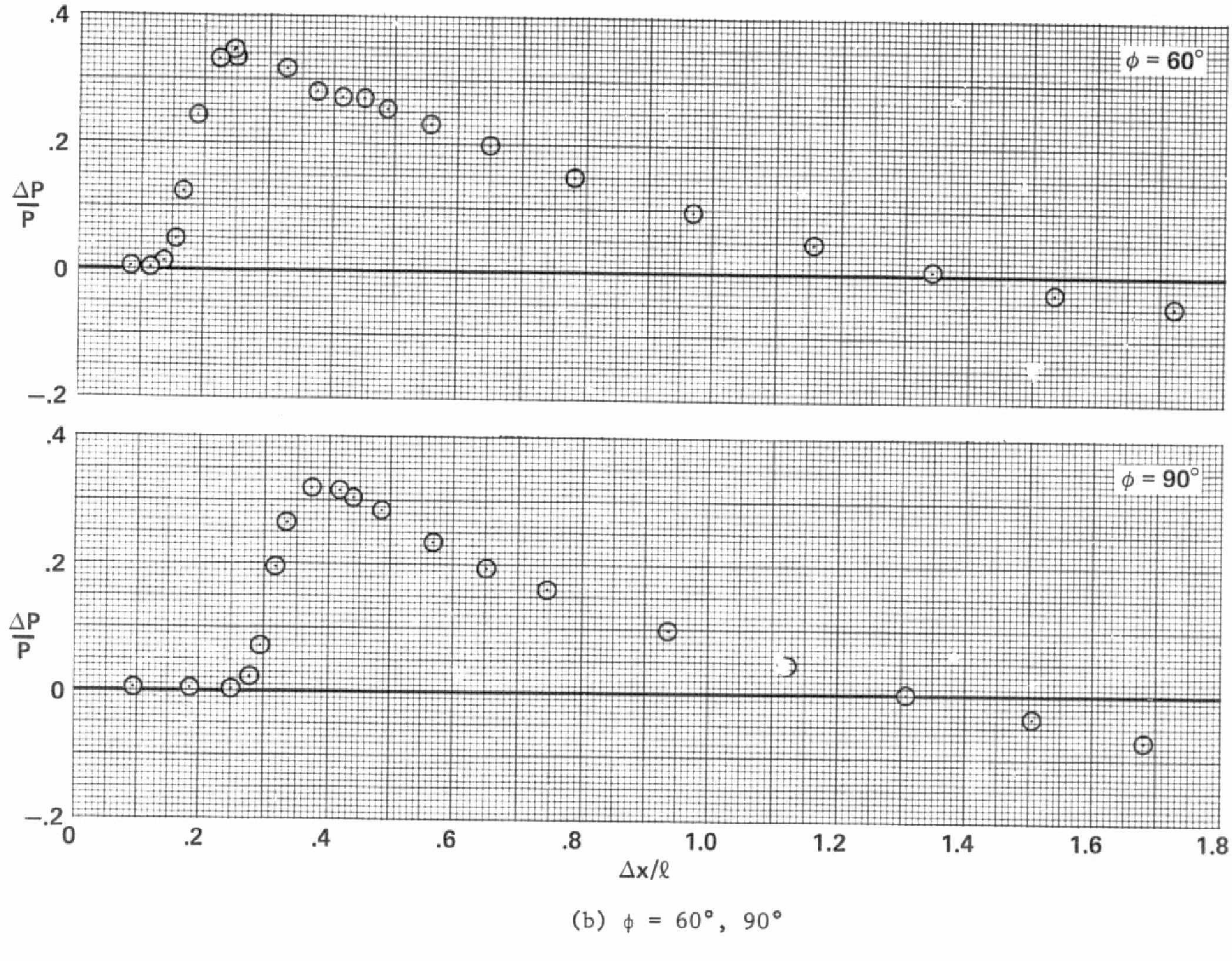
(c) $\phi = 120°$

Figure 44.- Concluded.



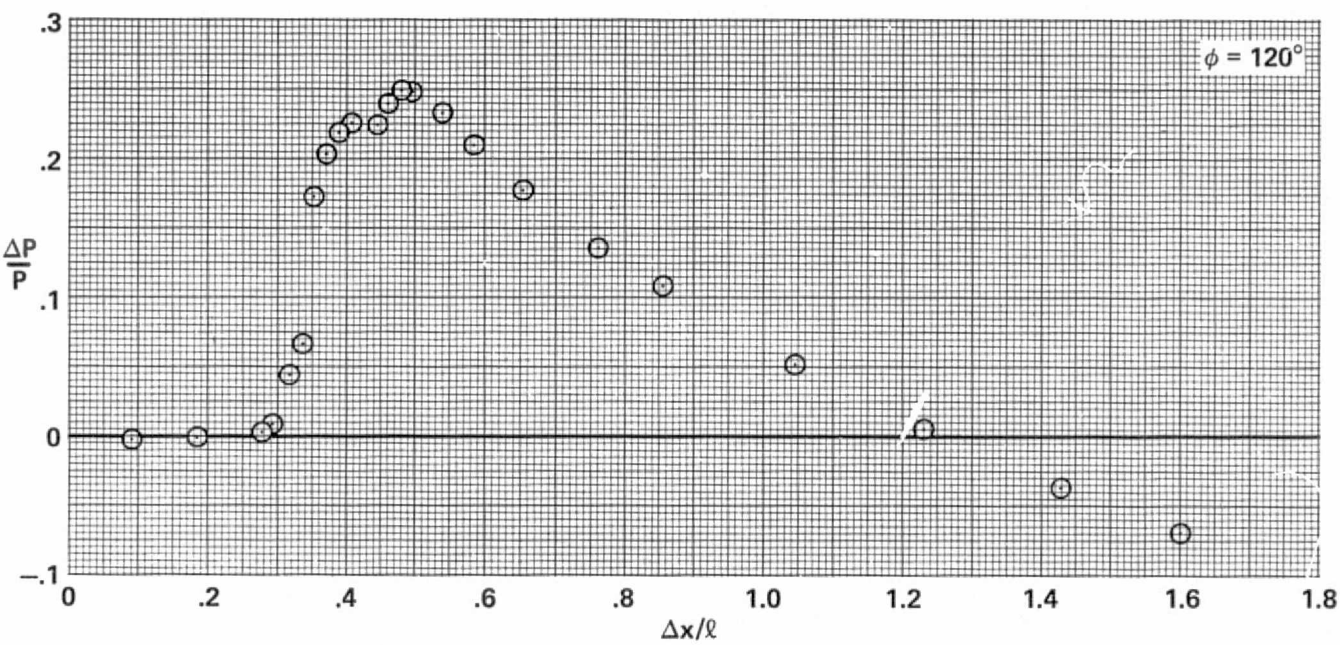
(a) ϕ = 0°, 30°

Figure 45.- Pressure signatures, M = 4.0, α = 10°, h/l = 1.18.



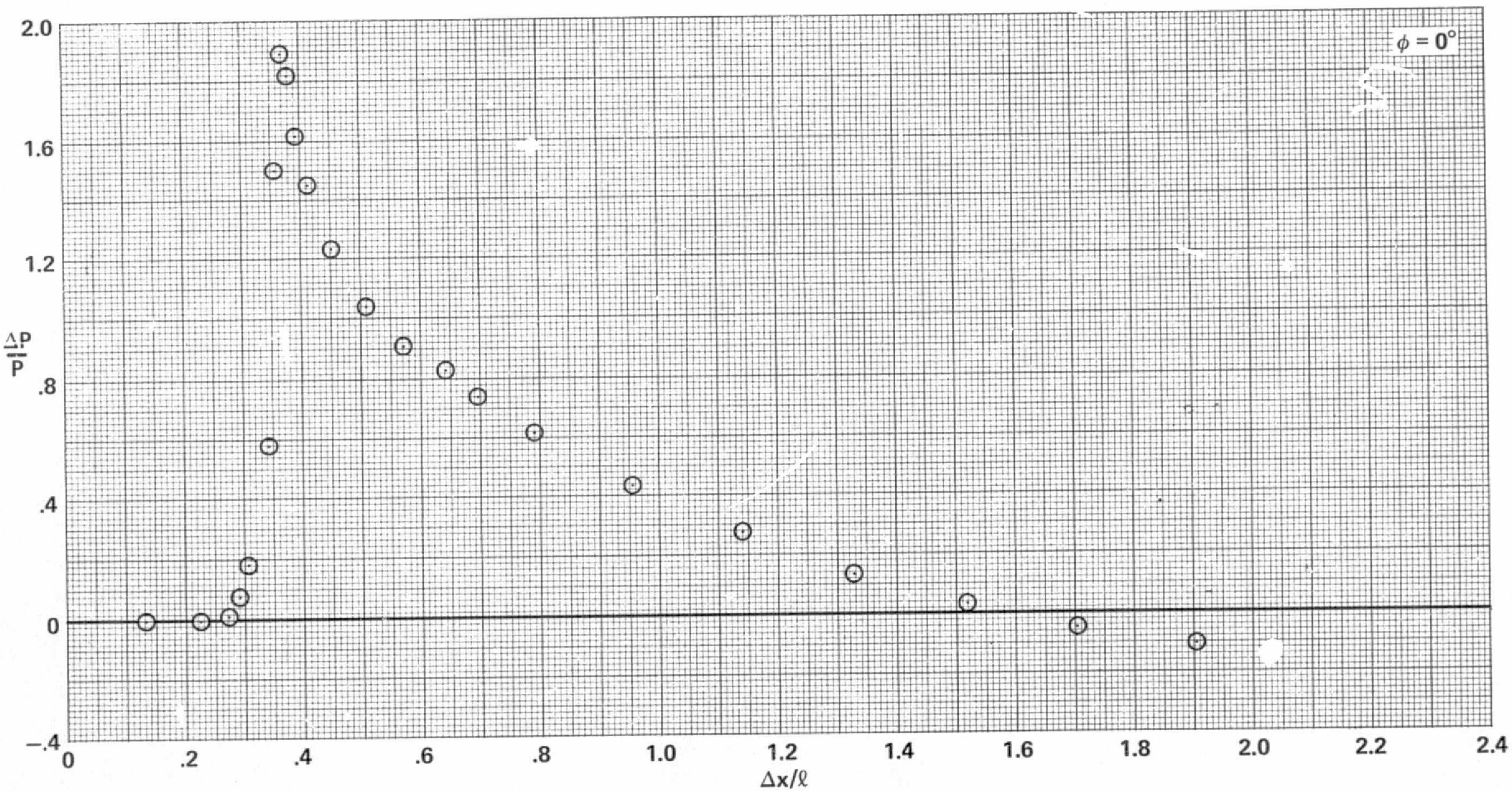
(b) ϕ = 60°, 90°

Figure 45.- Continued.



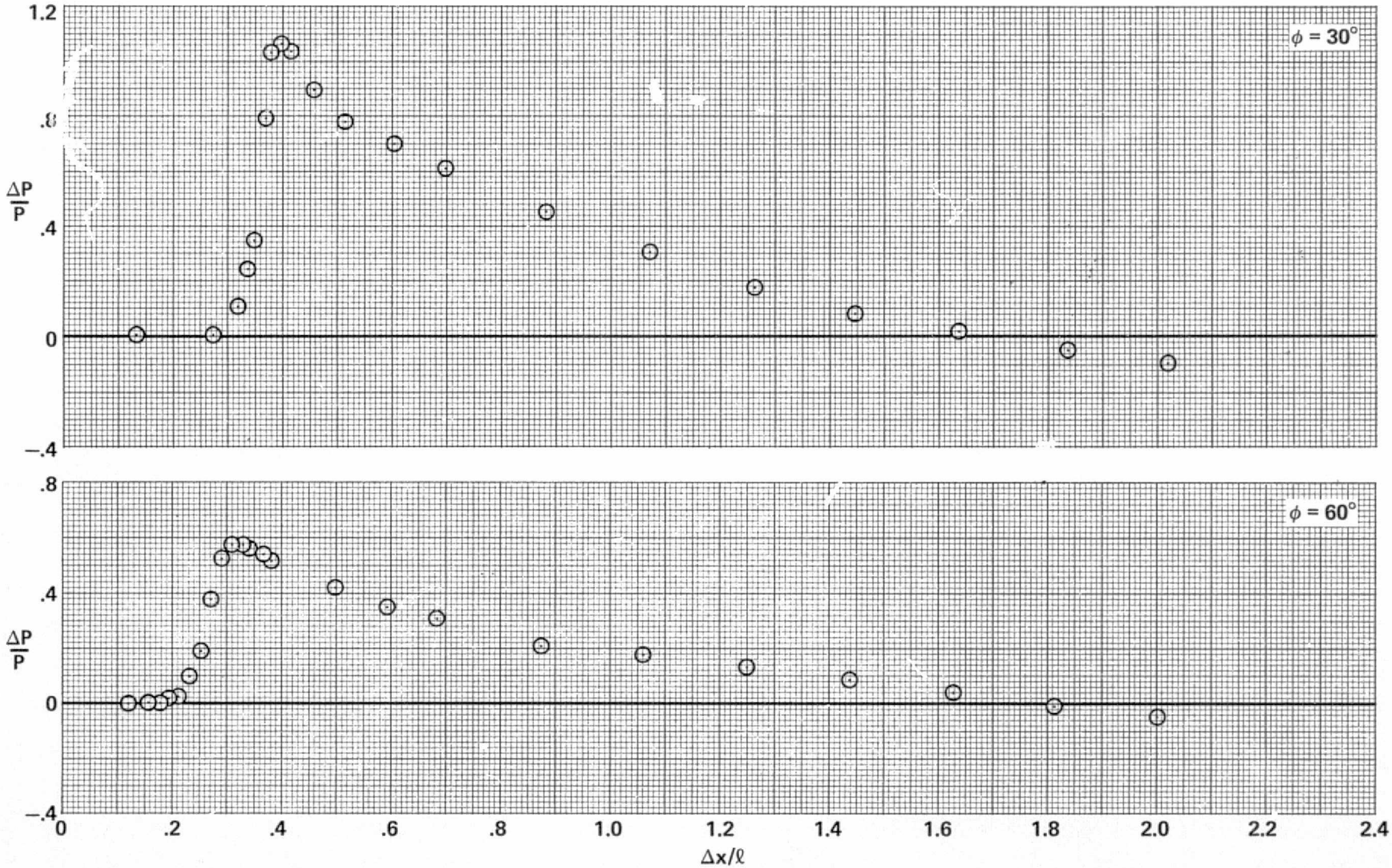
(c) ϕ = 120°

Figure 45.- Concluded.



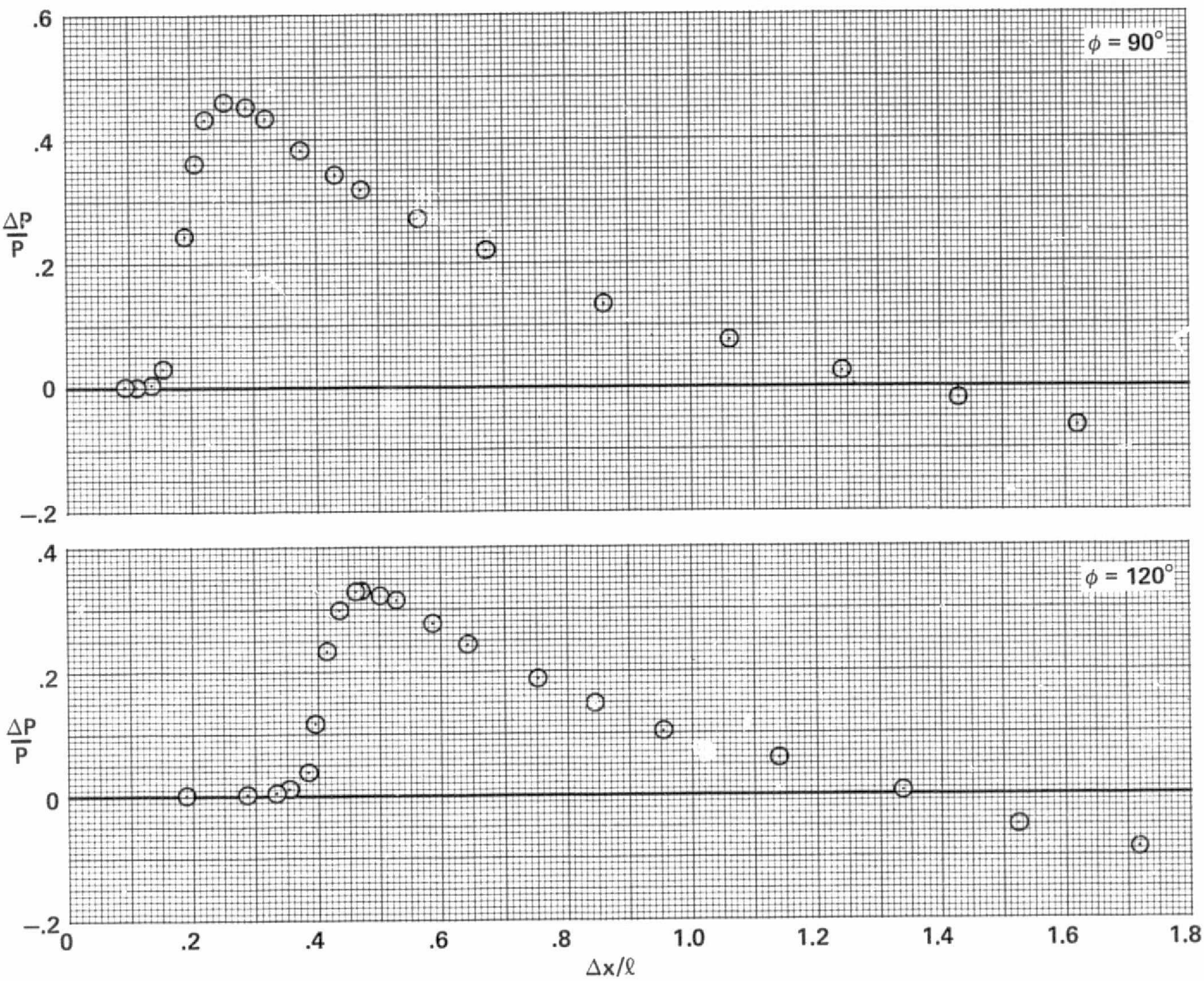
(a) $\phi = 0°$

Figure 46.- Pressure signatures, $M = 4.0$, $\alpha = 20°$, $h/l = 1.18$.



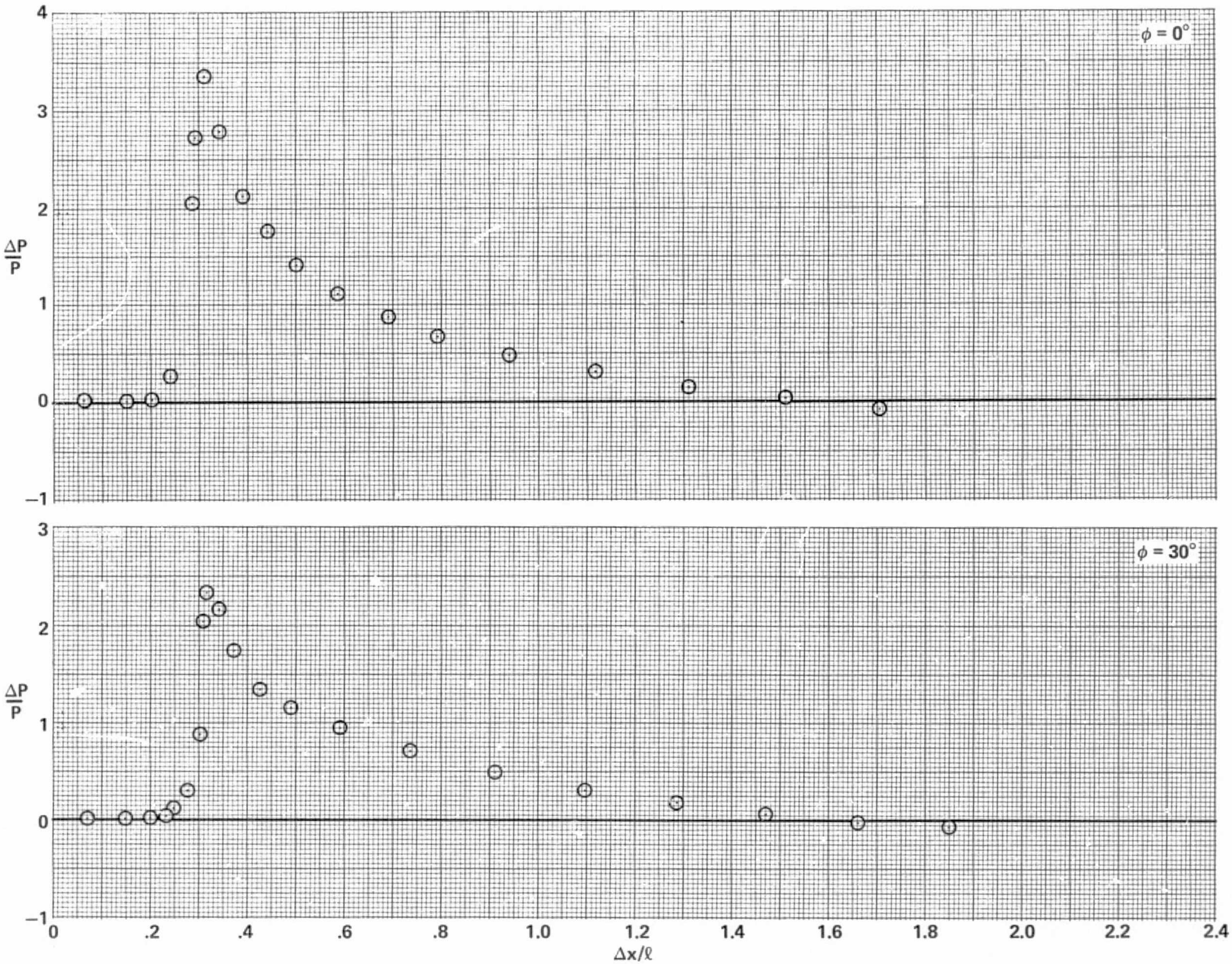
(b) ϕ = 30°, 60°

Figure 46.- Continued.



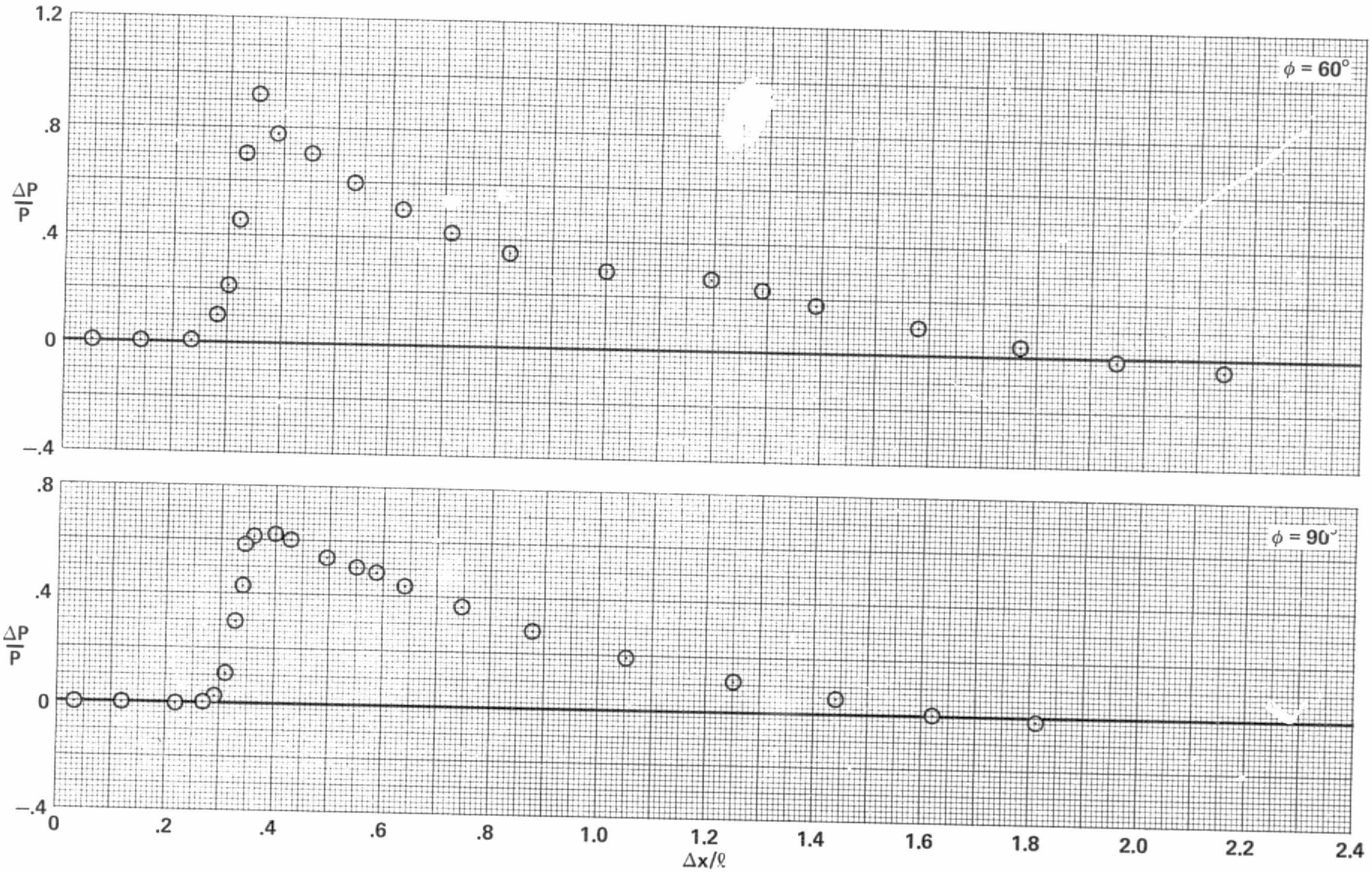
(c) ϕ = 90°, 120°

Figure 46.- Concluded.



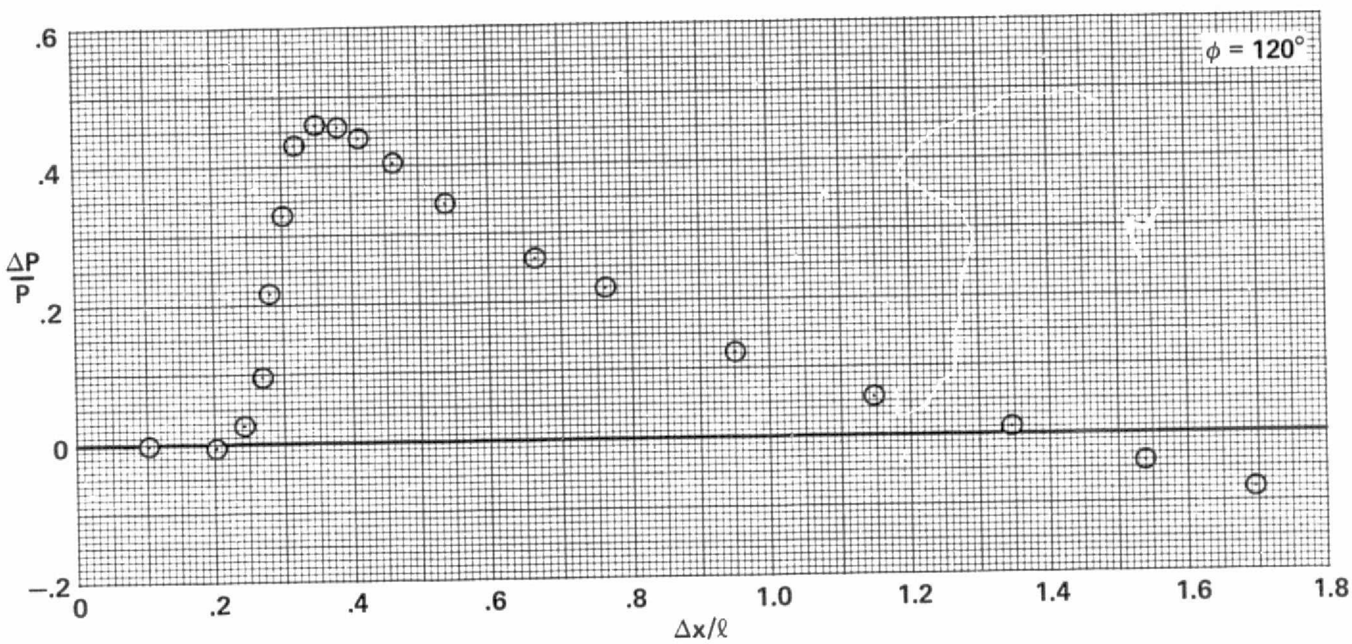
(a) ϕ = 0°, 30°

Figure 47.- Pressure signatures, M = 4.0, α = 30°, h/l = 1.18.



(b) ϕ = 60°, 90°

Figure 47.- Continued.



(c) ϕ = 120°

Figure 47.- Concluded.